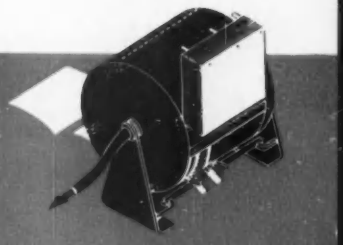
Control ENGINEERING

INSTRUMENTATION AND CONTROL SYSTEMS

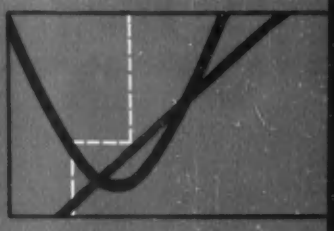
A McGraw-Hill Publication

75 Cents

FEBRUARY 1960



Computer Counts Ballots



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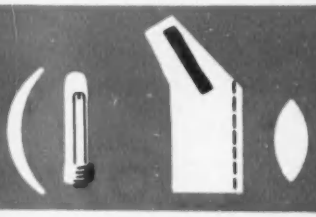
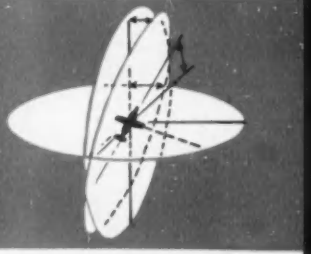
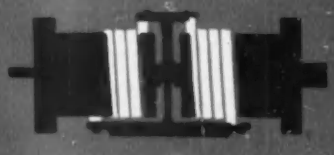


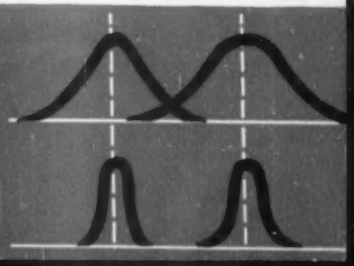
Dynamic Display Devices



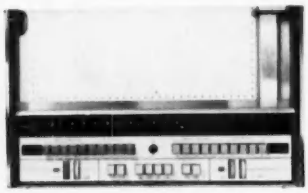
Better Inertial Indicators for Attitude & Heading



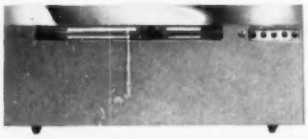
Mechanical Power Amplifier



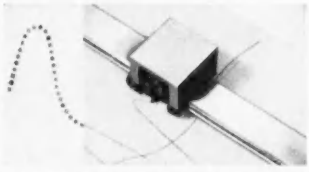
Evaluating Control Payout from Process Data



PUSH BUTTON PANEL controls operations rapidly, even at remote locations.

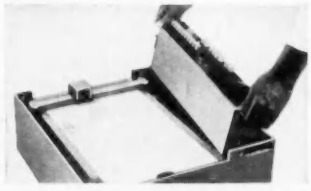


FLAT VACUUM PLATEN assures positive hold down of roll or sheet paper up to 12¼" width. Plot area, standard 10x15".

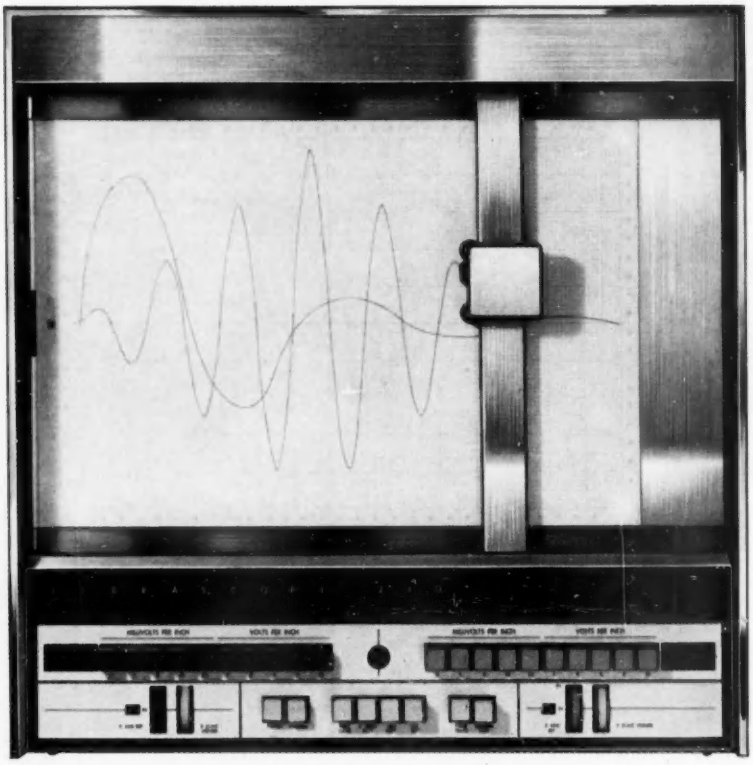


PRINTING FEATURES: Multiple symbol printing head—12 symbols...self contained ink supply.

Pen System—capillary action; splatter-proof. Point joiner available.



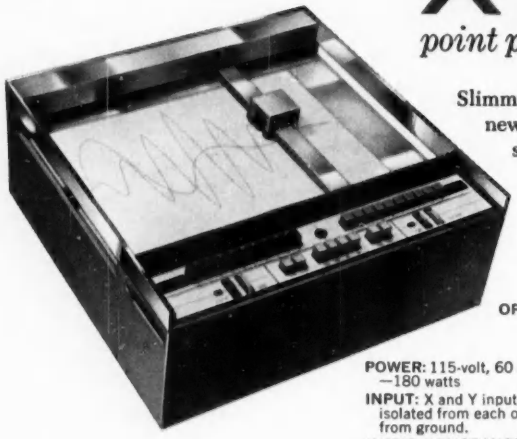
INTERCHANGEABLE MODULES add versatility...interchange with basic control section.



engineered for ease of operation...new

LIBRASCOPE X·Y PLOTTER

point plotting or continuous trace



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OPERATING INFORMATION

POWER: 115-volt, 60 cycle —180 watts

INPUT: X and Y inputs isolated from each other and from ground.

INPUT RESISTANCE: 2 megohms nominal on most scales. 1 megohm per volt on .5 millivolts per inch to .1 volts per inch scales.

INPUT SENSITIVITY: .5 millivolts per inch to 50 volts per inch with calibrated push button scales at .5, .1, .5, 10 and 50 millivolts per inch and .1, .5, 1, 5 and 10 volts per inch. Vernier controls permit continuous sensitivity adjustment between fixed scales, permitting full scale plotting for any sensitivity.

ACCURACY: Static .1%, dynamic .2% at 10" per second.

PLOTTER CALIBRATION ACCURACY: .05% on all scales.

SLEWING SPEED: 20" per second.

LI 9-20

For full details—dimensions, applications, list of accessory equipment, call our Sales Engineering Department or send for illustrated brochure on Model 210, XY Plotter.

For information on career opportunities at Librascope, write Glen Seltzer, Employment Manager.

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CIRCLE 189 ON READER SERVICE CARD

Photographed on location by Jack Beech.

Guesstimation or Automation?

While automation makes money for some manufacturers, others are still operating on intuition and "guesstimation."

The result? Many portland cement buyers are finding wide variations in quality—and many producers are noting wide variation in profits.

There probably is no more economical way to meet the requirements of your customers for high quality cement . . . no better way to meet demands for bag-to-bag uniformity . . . no faster way to modernize and compete in today's market . . . than with accurate and dependable measuring and control systems by Leeds and Northrup, *the most experienced* supplier of instrumentation to the portland cement industry.

Don't depend on "guesstimates," *be sure*. Let your L&N Field Engineer review your process and problem. Let him suggest from the wide range of L&N products, the *right* system to improve your product and process. Call him at your nearby L&N office or write 4918 Stenton Avenue, Phila. 44, Pa. Ask for our booklet, "Modern Practices in Rotary Kiln Instrumentation."

LEEDS Instruments LN NORTHRUP Automatic Controls • Furnaces

CIRCLE 1 ON READER SERVICE CARD

Epsco-West NEWSLETTER

Getting the Most for Your Money-

(In the Shortest Time)

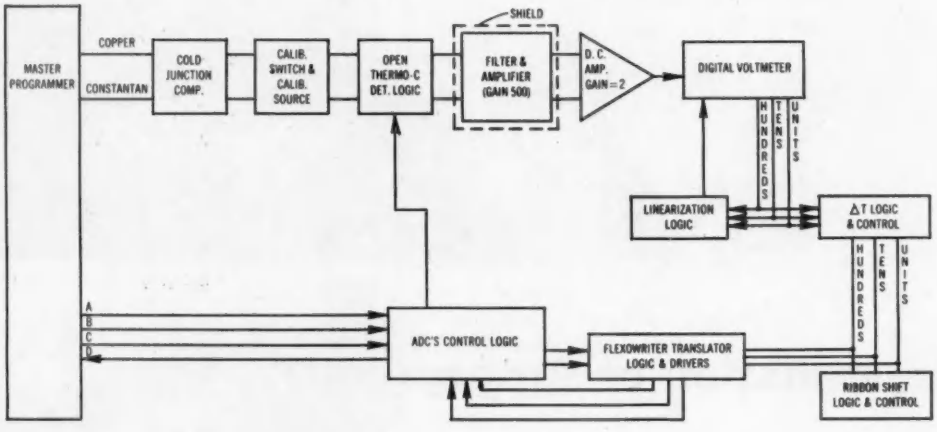
It may not be your worry how much a data handling system costs.

But it still may interest you to know that Epsco-West's design approach does make possible high-performance systems at minimum cost.

The biggest single factor is E-W's use of standard data blocks. These functional sub-assemblies, pioneered by Epsco, are field-tested and ready-to-work. Much costly design time is avoided, fewer components are needed.

The savings are substantial in delivery time as well as money. Typically, E-W users get their systems in operation two or three months earlier.

Case in Point—*E-W's novel temperature data logger for a major Northwest nuclear research center makes extensive use of standard building blocks. This low-cost solid-state system continuously monitors and records temperatures at 50 points in a reactor.*



Description—The system consists of a continuity tester, thermocouple bridge with cold junction compensation, low pass filter, differential amplifier, Epsco digital voltmeter, decimal to Flexowriter decoding network, buffer storage unit, and associated logic relay circuitry.

Function—The system will log thermocouple data from nuclear processing, linearize, scale the analog input information and present digital output in "real" quantities.

Overall Accuracy: 0.5%.

For more information about Epsco-West's capabilities, write for our free brochure, "First in Data Control." Please address Dept. 08-2.

4

For information about engineering opportunities at Epsco's progressive western division, contact H. Schwartz, Technical Placement Director.

Epsco-West

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Control ENGINEERING

FEBRUARY 1960
VOL. 7 NO. 2

Published for engineers and technical management men who are responsible for the design, application, and test of instrumentation and automatic control systems

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70 **Cyanamid's Approach to Computer Control**
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93 **Evaluating Control System Payout from Process Data**
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100 **Techniques of Dynamic Display—Part I**
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The CMC 700 Series is the only major breakthrough in counting, timing and frequency measuring equipment in the past 10 years. Here is the first successful application of transistors to high frequency counting and timing. Transistors perform all the functions in CMC's 700 series that required 63 tubes in old style counting equipment. These are the most reliable counters ever made.

TRUE DIGITAL LOGIC CIRCUITRY

By answering an obvious need for a completely new, up-to-date approach to counting and timing instrumentation, CMC has produced solid state instruments with greatly simplified circuitry, using logic "and" and "or" gates.

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Each 700 series instrument weighs only 27 pounds, measures 7 inches high, 17 inches wide, and 14 inches deep. Power consumption is a meager 46 watts, 1/10 the amount for vacuum tube models.

DO ALL THESE JOBS

Measure frequency from dc to 10 mc, time interval from 0.1 μsec, ratio 1 cps to 1 mc and unlimited multiple period selection. Frequency converters available for higher frequencies. The counter also generates time interval marker pulses from 1 μsec to 1 second. Data can be presented on standard decades or inline Nixie tubes. The 700 series will operate digital recording equipment, punches, inline readouts, and other data handling gear.

These Features, Too—Decade count-down time base—frequency divider circuits never need adjustment. Accuracy, ±1 count ±oscillator stability. Sensitivity, 0.25 v rms; input impedance, 25 k ohms/volt.

And The Price—Higher than vacuum tube models. But you can save the difference on down time in the first year. Model 727A Universal Counter-Timer, $3,500; Model 707A Frequency-Period Meter, $2,700; Model 757A Time Interval Meter, $2,500. Rack mount optional at no extra cost. All prices f.o.b. Sylmar, California.

More Information Available – Your nearby CMC engineering representative will be happy to arrange a demonstration and provide you with complete technical information. Or you may write Department 082.

CMC **Computer Measurements Co.**
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CIRCLE 5 ON READER SERVICE CARD 5

SHOPTALK

From the bid request to the prototype

Way back in the early fall of 1956 the Los Angeles County Board of Supervisors put out a request for bids on an automatic ballot tallying system. The purpose: to obtain a data handling system that would bring order out of a voting chaos caused by the unusual voting problem and unique geographic structure of the county. To bring the urgent request to a maximum number of control system suppliers, the board asked CtE to publish the details of the system requirements (see "Problem Forum", November 1956, p. 6). Sixteen companies answered the call, submitted proposals.

Now, over three years later, the fruits of the publicity pays off, for the county and for CONTROL ENGINEERING. On page 65 Bill Bell describes the prototype of an extremely interesting mechanical ballot handling/electronic data handling system that it is hoped will dig Los Angeles from under a mountain of ballots.

Production analyst spans the field

Educated in chemical engineering at Princeton University, Herbert Grohskopf has been concerned with production analysis since he joined American Cyanamid in 1950. Taking a broad view of the responsibilities of the production analysis group, he began building a chemical engineering staff with skills in experimental statistics. Now as manager of the Production Analysis Section, Herb has added personnel qualified in process mathematics, numerical analysis, and control engineering. With the section he manages now at work on an integrated study of a multistage process at Cyanamid's New Orleans plant, Herb hopes to evaluate both advanced methods of chemical process engineering and applications of computer control. For a summary of his thoughts turn to "Cyanamid's Approach to Computer Control" which appears on page 70 of this issue.

Choice items from March

Here's a preview to whet the appetite: techniques and equipment for digital data conversion, tiny electronic controls run giant coal digger, case studies show progress in simplifying maintenance, a new way to look at the process control center, applying probability theory to automatic control systems, and many others.

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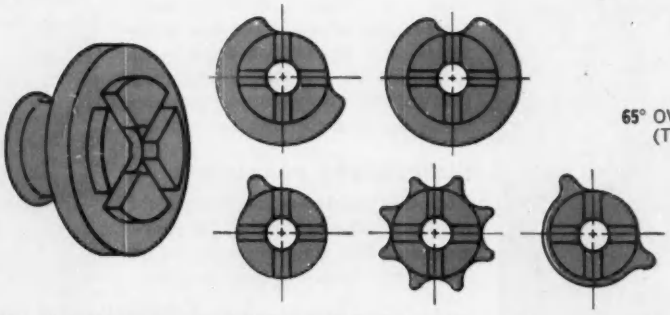
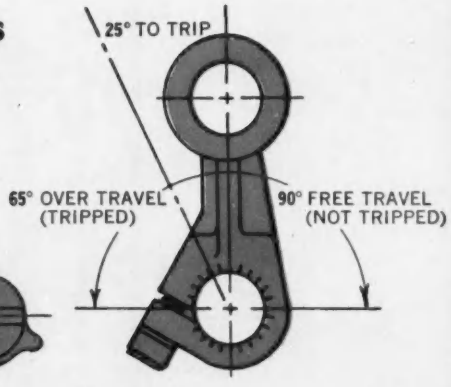
Closely Check These Outstanding Features





1. Infinite Operating Flexibility . . . One simple interchangeable cam controls contact sequence . . . performance can be tailored to the specific needs of each application.

2. Ample Overtravel and By-pass . . . Sixty-five degree overtravel . . . 90° by-pass . . . 180° arc.

3. Clockwise or counterclockwise motion . . . Converting from clockwise to counterclockwise motion takes but a few seconds . . . no tools required.

4. Light operating pressure . . . Tripping action is 50% less than previous models. Overtravel action requires only 8 pounds at 1½ inch radius.

5. Shock-proof Mechanism . . . Positive mechanical lock . . . prevents accidental movement due to shock or other external causes.

6. Faster Contact Action . . . Make and break speed up to 50% faster than predecessors . . . assures foolproof operating and wards off destructive arcing.

7. Greater Contact Pressure . . . Contact bounce minimized by use of new contact material that permits four times greater contact pressure.

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FEEDBACK

APPLICATIONS FORUM

A controls engineer in a manufacturing engineering department shows how he would draw on his trouble shooting experience to simplify control of a conveyor line. Submit your methods of simplifying other control systems. Submit your problems, too. Both will earn rewards if published.

To the Editor—

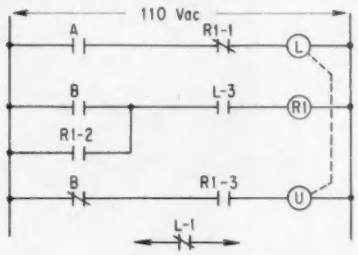
The article entitled "Simple Circuit Controls Spacing on Conveyor Lines", page 155 of the November '59 issue, shows some very shrewd thinking on the part of author DeLoache, but looking at his circuit from the standpoint of an ex-maintenance man, recently promoted to controls engineer, I question two items of interest in trouble shooting:

1. To depend on the differences in relays to prevent contact races is hazardous because of changes in drop-out and pull-in times caused by long exposure of the relays to ambient conditions in a lot of plants, as well as normal wear and tear.

2. If a resistor-relay combination is used as in this circuit, it means that exact replacement parts must be available at all times in order to make a fast repair.

In our particular line of business, we find it mandatory to use standard machine tool relays in our circuitry lest we be criticized for extended down time resulting from delays in getting the proper replacements. Any repair parts in our stores, not used within a certain length of time, are scrapped or sold, and not reordered.

A circuit that we might use is shown. It has one less component than DeLoache's.



When beam A is broken, L is latched through NC R1 which stops belt 1. When beam B is broken, R1 is energized and sealed in through R1-2 and L-3. This closes NO R1-3 and sets up a circuit to energize U, which will unlatch L when the part clears beam B, restarting belt 1.

I congratulate the staff of Control Engineering for many jobs well done in the past. I have been a steady subscriber for the last four years, and I find your articles among the most informative I have ever read.

M. A. Keasal, Jr.
Metal Stamping Div.
Ford Motor Co.
Monroe, Mich.

System buyers must read Bell's article.

To the Editor—

Mr. Bell's article on bid requests (November '59 issue) should be required reading for all buyers of development equipment, not only for the information it contains but also as an indication of the complexity of the problem. A lot more could be said on the subject than the space for a brief article permits.

In particular it would seem that more emphasis ought to be placed on acceptance testing. The purchase specifications should state clearly the procedures used in determining whether the delivered equipment has met the promised reliability and performance specifications. If this is not done, the manufacturer may be encouraged to exaggerate the performance claims for his proposed equipment because the acceptance conditions are too vague.

C. L. Emmerich
Norden Div. of United Aircraft Corp.
White Plains, N. Y.

Fabricator wants to automate.

To the Editor:

Can you give me a bit of information on automation?

Being an inventor, I intend to manufacture patented house trestles. These light-weight table-height horses must be precision built, to be rigid

FEEDBACK

industrial servovalves

rugged, reliable . . .

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The Moog Series 71 electrohydraulic servovalves excel in all industrial applications that require superior performance combined with rugged reliability. A low sensitivity to oil contamination plus a large field-replaceable filter provide optimum performance for extended periods of time. Immediate production requirements can be accommodated from stock in flow ranges from 0.25 g.p.m.

one of the industrial products group including:

High flow servovalve, valve positioner servo amplifier, (illustrated at left). In addition: integrated hydraulic power packs, mounting manifolds and hardware, electrohydraulic servo-actuators can be provided.

Moog's Industrial Division was established for the purpose of developing commercial applications for electrohydraulic servomechanisms and to serve industry in this new and rapidly growing precision control area. The division offers both integrated electrohydraulic control systems and a complete line of servocomponents.

SEE FACING PAGE FOR ADDITIONAL INFORMATION

MOOG SERVOCONTROLS, INC. INDUSTRIAL DIVISION EAST AURORA, N. Y.

and well balanced at this height. My problem is holding down the cost.

As all leg bevels are alike, instead of sawing the slow hand way with a shop saw, can some simple automation method be worked out? Can an automatic device be built, so the leg slats can be placed in one end of the apparatus, cut the lower and upper leg bevels, and then stamp indent the nail guide holes, and kick out the leg on the other end? Can you refer me to several firms who could make such an automation device?

Clem Ernst
Gallaher Building
Sidney, Ohio

We suggest the following:

1. Barkley & Dexter, Inc., 50 Frankfort St., Fitchburg, Mass., Robert G. Dexter, president. This organization has produced all types of novel automatic equipment, such as pretzel-bending machinery, automatic packaging devices, etc.

2. Machinery Electrification, Inc., 56 Hudson St., Northboro, Mass., Donald R. Percival, president. This outfit could undoubtedly do the engineering on the necessary equipment, but might farm out the manufacture.

3. Automation Development Corp., 135 Reynolds Rd., Mentor, Ohio—F. F. White, president. This is a small organization which has done several successful jobs. They have developed one machine that automatically formed patterns of different colored and different shaped floor tile.

4. Planet Corp., Lansing, Mich. They have successfully developed a programmed arm for automatic material transfer. Ed.

Wants pneumatic computing elements.

To the Editor—

I am interested in obtaining more information on the pneumatic computing elements you wrote about on page 21 of the December '59 issue. For example, are these units commercially available, can they be used to divide 3 to 15 psig signals, and what accuracy and repeatability can be expected?

J. L. Moore
Williamsville, N. Y.

As far as we know the pneumatic computing elements mentioned in "Newsbreaks" in the December issue are not yet commercially available. For additional information we suggest you write directly to Dr. R. E. Bowles who is head of the project at the Diamond Ordnance Fuze Laboratories, Washington 25, D. C. Ed.

What you should know about Analog Computers

Judging from the literature, most discussion of analog computers turns on form rather than function.

Every computer manufacturer, including Donner, is ready to tell you all about their designs, right down to the last microvolt. Few spend their literary effort in telling you how to use them and what kind of problems are amenable to analog computer solution. Not too strangely, this is what you, the prospective user, wanted to find out in the first place.

The Donner 3400 Desk-top Computer functions as a compact, versatile electrical model of a dynamic system.

HOW AN ELECTRONIC ANALOG COMPUTER SOLVES PROBLEMS

A mathematical expression which defines the dynamic behavior of a particular physical system also describes the behavior of all other analogous systems. A general purpose analog computer can be programmed to behave as one of these analogous systems. So programmed, it can be used to explore the characteristics of the system or to "solve" the describing equations. Typical problems range all the way from explaining the laws of classical and modern physics to the physiological relations of life itself. Here are some of the fields where analog computers are in use: antenna design, medical research, cybernetics, electron trajectories, nuclear reactor design, fluid mechanics, heat transfer analysis, aerodynamics, meteorology, classical and nuclear physics, chemical kinetics, petroleum, engineering, servo system analysis, auto- and cross-correlation, and economic forecasting.

Assembly of Donner 3100 series high accuracy medium size analog computers in quantity lots provides the user with more value at lower cost. Complete Donner 3100 Computer Consoles start at just under $11,000.

Basic computing elements in an electronic analog computer are dc amplifiers, precision components (resistors, capacitors, and potentiometers), and non-linear accessories (multipliers, function generators, and transport delay simulators).

By interconnecting the computing elements at a patchboard, varying voltage amplitudes can be integrated, summed, differentiated, multiplied, divided, altered in non-linear fashion, and otherwise operated on as directed by a mathematical equation. The answer, which appears as a varying voltage, can be visually observed on a voltmeter or an oscilloscope and permanently recorded by any one of several plotting devices.

The analog computer user can take an equation, change the coefficients at will, and get whole sets of solutions with amazing ease and speed. He can get these results to accuracies of 0.1% or better for a very modest investment. Small Donner computers begin at just over $1,000.

ANALOG OR DIGITAL

The chief advantages of the analog technique are speed, economy, and flexibility. With the analog computer, you get a genuine insight into the response of the system to both internal and external stimuli. No other approach can bring the investigator into such intimate contact with the system.

Digital computers sometimes provide more accurate results, but they seldom give the user the same knowledge because they are at best only machines that compound arithmetic information. Unlike digital computers, analog computers actually behave just like the simulated systems.

TWO NEW PUBLICATIONS PROVIDE MORE INFORMATION

If you are interested in learning more about the application of analog computers, copies of Donner Tech Notes #1 and #2 are available from your nearby Donner engineering representative or directly from the factory. Tech Note #1 is titled "How to Simulate a Non-Linear Control System with an Analog Computer;" Tech Note #2, "How to Use and Program Analog Computers."

Donner Scientific specializes in the manufacture of accurate fixed and general purpose analog systems designed to analyze, measure, and control dynamic inputs. Complete technical information and informed applications assistance can be obtained from your nearby Donner engineering representative or writing Dept. 082.

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24

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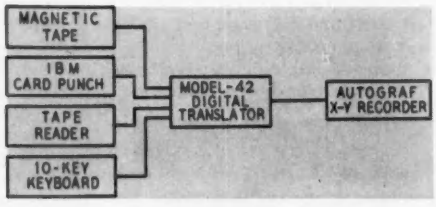
- 0.1% conversion accuracy
- Permits cartesian plotting of digital data
- Accepts card, perforated tape, magnetic tape, or manual keyboard inputs
- High-speed transistorized control circuits
- Accepts 4 digits and sign per axis; front panel display of matrix contents

Moseley Model 42 Digital Translator allows automatic operation of Autograf or similar X-Y Recorders from digital data supplied by any conventional source. Accuracy of digital-to-analog conversion is 0.1% and the accuracy of Moseley AUTOGRAF recorders, 0.15%, is maintained.

Model 42 is compatible with IBM Summary Punches and Card Readers including Models 514, 519, 523, 524, 526, etc. It may also be driven, without modification to either the Translator or driving equipment, by mechanical punched tape readers such as Friden, Soroban solenoid and Teletype motorized readers.

Model 42 is supplied with a 10-key serial keyboard for manual input. Accessories include magnetic tape adapter, Flexowriter converter, remote decimal contents read-out panel and optical magnetic tape converter. Model 42, including keyboard, $3,450.00.

Data subject to change without notice. Prices f.o.b. factory.



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John M. Morgan

from pushbutton to tape controls

Jack Morgan is one man who can testify to how important control systems engineering has become to the machine tool industry. Now manager of the Development Research Dept., Machine Tool Div. of the Cincinnati Milling Machine Co., Jack has seen the control content of machines grow from a few pushbuttons and limit switches to the complex systems of today. Jack and his group get involved in all kinds of high level projects: photoelectric line tracers, two- and three-dimensional electrohydraulic templet followers, numerical positioning and path controls, even electrodischarge and electrolytic machining processes.

Morgan ranks numerical control as the most important development to come along since the start of machine tool electrification. That is why he is pushing hard to help it get off to a good start—to get some minimum standards on the books before machine shop floors become lined with a hodgepodge of incompatible systems. He heads an Electronics Industries Association subcommittee on numerical machine tool control, which has already proposed a standard code for perforated tape.

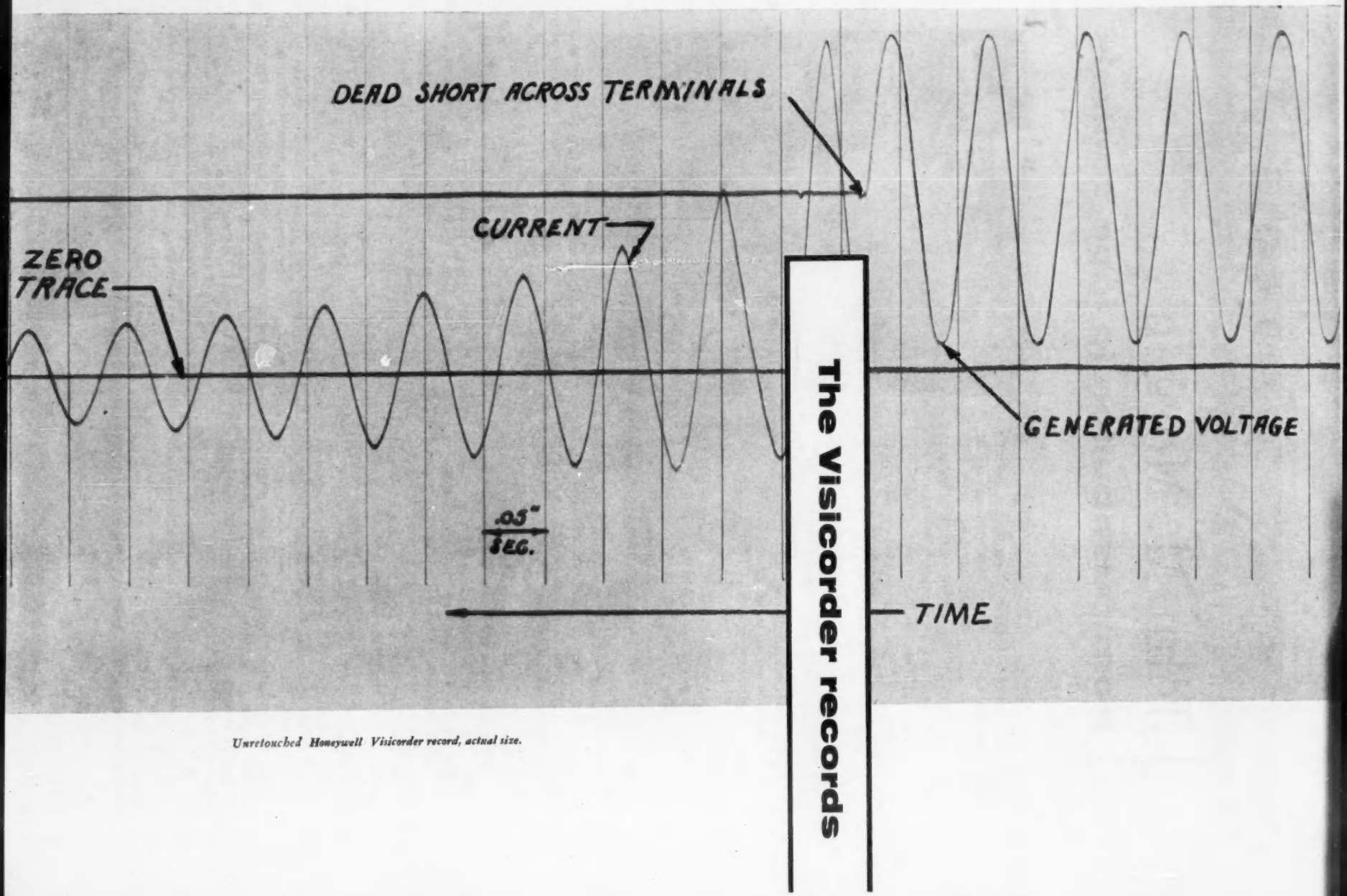
All of his formative years were spent in the sunny climate of New Mexico. Morgan attended grade school and high school in Raton, then traveled to Albuquerque, home of the University of New Mexico. In 1941 Jack graduated from the university with a degree in electrical engineering. The "woman behind the man" entered Jack's life early—in 1938, to be exact—when he married Georgia Sale. As Jack proudly admits, Georgia contributed much to his start in the engineering profession by giving moral encouragement as well as bringing home a weekly paycheck to help meet tuition costs and household expenses. His trusty trombone also did its share during those lean college years. Morgan's Varsity Club Orchestra was in great demand for dances.

After graduation, he showed no small amount of courage when he traded Southwestern sunshine for the cold winds of Schenectady, N. Y. Jack quickly became involved in a number of intriguing and diversified design projects, such as G. E.'s Thymotrol packaged electronic adjustable speed drive, the lighting controls for New York City's famed Radio City Music Hall, and current regulators for the atomic bomb project at Oak Ridge. Probably his most important systems engineering job at G. E. was the design of two- and three-dimensional tracing systems, the first of the really complex controls for machine tools. Jack recalls with a smile that the maze of pushbuttons incorporated on the prototype earned it the nickname, Morgan's Organ.

His work at G. E. received sufficient notice to win for him the position of chief electrical engineer of Cincinnati Milling in 1947. He retained this title until 1954 when he advanced to his present position.

Morgan's confidence in the growth of the part that electronics will play in the future of the machine tool field has had a profound effect on his extracurricular activities. Each year his face and voice are seen and heard at many meetings of technical societies and industry committees. Among his credits are ex-chairman of the electrical standards committee of the National Machine Tool Builders' Assn., member of the NMTBA numerical control committee, and a director of the AIEE Cincinnati section. Jack is looking forward to 1963 when the AIEE Machine Tool Conference will be held in Cincinnati. He will be meeting general chairman.

This busy control engineer is involved in scouting, too, as one might guess of the father of four sons: John, 21; George, 16; James 12; and Fred 11. John is attending Ohio University and the three others have college hopes too. The elder Morgan is relieved that for a few more years there will be just one college student at a time. But then Jim and Fred will double up, and the bills will soar. So Jack Morgan is keeping his trombone handy—just in case.



Unretouched Honeywell Visicorder record, actual size.

This study of the drop in voltage load on an Allis-Chalmers alternating current generator was directly recorded by a Model 906 Honeywell Visicorder.

In this transient reactance test, made by design engineers at the Allis-Chalmers Norwood Works, the generator was operated at full voltage, and then a dead short was applied to the terminals. When such a sudden load is thrown upon a generator, the voltage drops because of the inherent characteristics of the generator. This voltage "nosedive" is so rapid that a voltage regulator cannot immediately correct the voltage and bring it up to normal. Because of this time delay while the regulator is catching up, motor contacts and other devices on the line may drop out, lights may blink objectionably, and electronic devices may function erratically. For these reasons, these studies of time as related to generator characteristics are very important to better generator design. The Visicorder's ease of operation, calibration, and immediate readout made it ideal for these studies.

N. O. Risch and F. R. Manning, design engineers at Allis-Chalmers Norwood Works, study a Visicorder chart of voltage-drop tests on a generator.

generator voltage load-drop

The Honeywell Visicorder is the pioneer, completely proven, and unquestioned leader in the field of high-frequency, high-sensitivity, direct-recording ultra-violet oscillography. Here are some of the reasons why Visicorders provide the most accurate analog recordings available: constant flat response and sensitivity of galvanometers; grid-lines simultaneously recorded with traces to guarantee exact reference regardless of possible paper shift or shrinkage; flash-tube timing system for greater accuracy of time lines; superior optics for maximum linearity of traces.

No matter what field you are in . . . research, development, computing, rocketry, product design, control, nucleonics . . . the high-frequency (DC to 5000 cps) Visicorder Oscillograph will save you time and money in data acquisition.

Call your nearest Minneapolis-Honeywell Industrial Sales Office for a demonstration.

Reference Data: write for Bulletins 1108, 1012, and HC906B.

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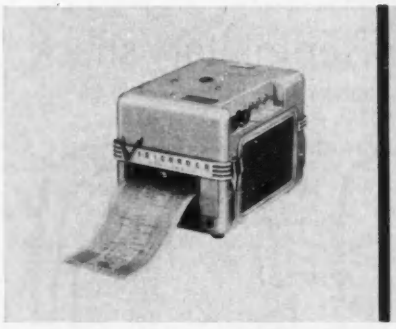
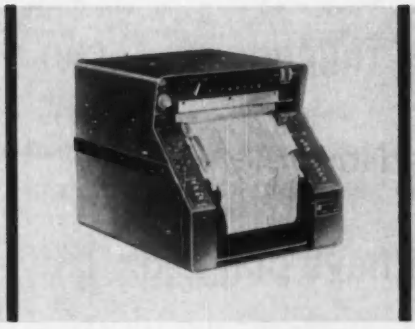


Recent Models of the 906 Visicorder incorporate time lines and grid lines and record up to 24 simultaneous channels of data.



The NEW Model 1108 Visicorder, with many automatic features and the convenience of pushbutton controls, is ideal for intermediate uses requiring up to 24 channels of data.

The Model 1012 Visicorder is the most versatile and convenient oscillograph ever devised for recording as many as 36 channels of data.

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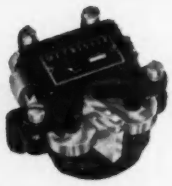
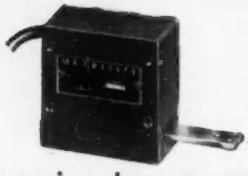
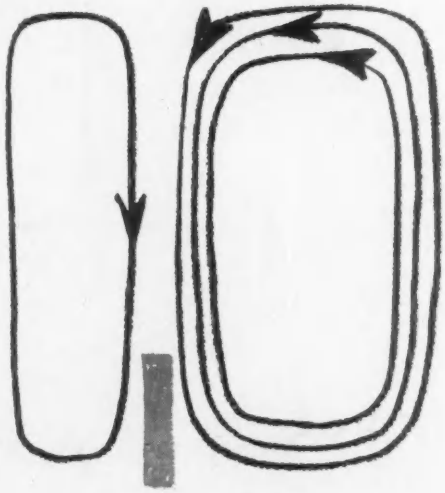
PIONEERING THE FUTURE

Metrisite... is the only  device available today that  provides a near-perfect combination of ideal transducer characteristics. The unusual properties of this remarkable new motion-sensing development are: extreme resolution...  easily measures one ten-millionth of an inch; minute operating force... absolute minimum bearing friction; negligible reactive force... a fraction of a milligram; true linearity... a proven accuracy of 1/10%; high electrical output... up to 100 volts without amplification; wide range of shapes and sizes... from sub-miniature on up; exceptional ruggedness... can meet military shock and vibration tests. Now, many of the obstacles that have plagued control technology can be eliminated. Write for Metrisite details.



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DIVISION OF
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CIRCLE 18 ON READER SERVICE CARD

At Oil Company's School

CtE
FEBRUARY
1960

Newsbreaks In Control

● Chance Vought Strengthens Position in Process Control

Los Angeles—Merger negotiations are underway between Panellit, Inc., Information Systems, Inc. (a Panellit subsidiary), and Genesys Corp., wholly-owned subsidiary of Chance Vought Aircraft, Inc. CONTROL ENGINEERING has learned. Chance Vought is to own 80 percent of an expanded electronics and computer operation formed by the merger of Information Systems and Genesys. The newly formed company will then buy Panellit, Inc., which will continue its operations unchanged, supplying panelboards, alarm systems, and instrumentation to the process industries.

● Automatic Monitors Near for Hospital Patients

New York—An automatic monitoring system that will allow a hospital nurse at a central control station to watch a large number of patients simultaneously will soon be installed. Gulton Industries, which has designed the system, expects to announce a first sale next month. Each patient will have a set of sensors and a signal conditioning unit at bedside to send internal temperature, respiration, electrocardiogram responses, and heart sounds back to a central nurse's station. Nurse will watch these variables on a visual display, listen to hear heart beats, and also observe each patient through closed circuit TV.

● Tape Controls to Speed Tailpipe Bending

Hamilton, Ohio—A punched-tape controlled tailpipe bending machine will make the job of inventorying tailpipes easier for service stations. Instead of maintaining an inventory of tailpipes for all makes and models of automobiles, muffler service shops will take from a supply a punched tape corresponding to the model of car to be serviced, insert it in the machine, and bend the pipe to fit to proper shape—automatically. The machine, built by Baldwin-Lima-Hamilton, will use General Electric numerical control; it will be marketed by the Nu-Era Corp.

● Sub Guidance System for Instrument Tracking Ships

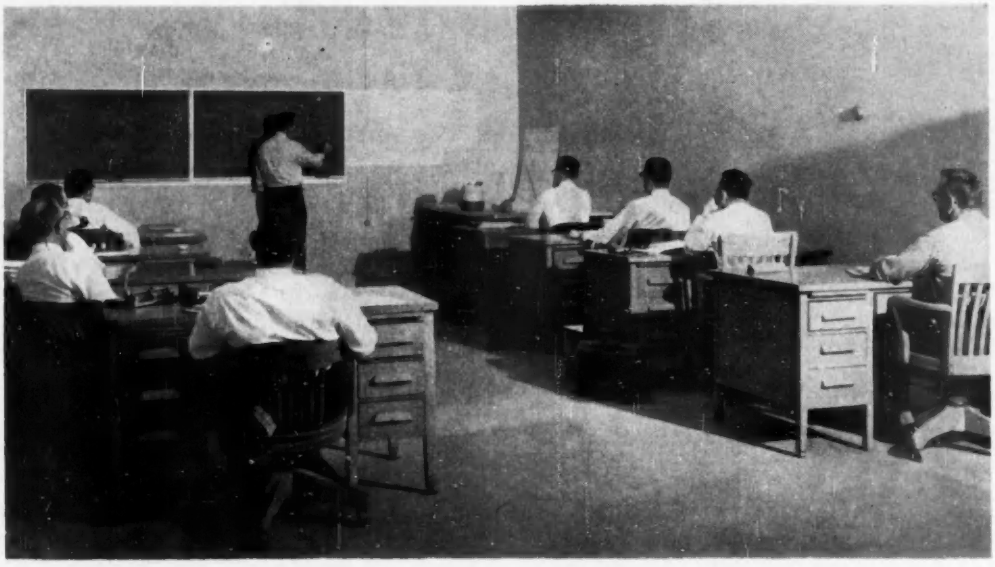
Cape Canaveral—An Atlantic Missile Range instrumentation ship is to be equipped with a ship's inertial navigation system (SINS), the autonavigator being incorporated in Polaris missile-firing submarines. Purpose of the installation: to locate accurately the instrumentation ship during tests of the Army's solid propellent Pershing missile.

● Computers Pick up Pentagon Supply Load

Washington—The Department of Defense has installed 170 business-type electronic computers to keep track of and to process orders for the 3.5 million different items stocked at 2,700 warehouses around the world. This year the Pentagon will pay $111 million for rental of the machines which are located at 60 different supply installations.

WHAT'S NEW

At Oil Company's School . . .



. . . LECTURES . . .

. . . start the training day. Shell Development chemist S. E. Steinle uses the board in the trainees' room.

. . . STUDY . . .

. . . periods are interspersed throughout the day to solve assignment problems. Students Caillet and Cannon (standing) talk one over.

. . . EXPERIMENT . . .

. . . with electronic devices is required to understand principles of measuring devices. Shell Development engineer K. Edinborgh (second from right) explains a setup to students Price, Roodzant, and Vidaurri (left to right).

WHAT'S NEW

. . . AND APPLICATION . . .

. . . of measuring devices is the major interest at school. Shell Development engineer, R. D. Cook, (center) describes the workings of the gas-liquid chromatograph to students Caillet, Bingham, Cannon, and Skelly.

SAN FRANCISCO—At Shell Development Corp.'s Emeryville laboratory one day last month, eight instrument engineers celebrated the passing of a halfway-point. The eight, one from each of Shell's refineries in the U.S. and Canada, have completed the first part of Shell's new intensive 9-month training program which is to supply the oil company's refineries with experts in the application, installation, and maintenance of quality measuring devices.

Since September the trainees have followed a tough curriculum (see chart), administered by Shell Development's Instrumentation Div. under the direction of D. J. Pompeo, department chief. Although instrument engineers have been coming to Emeryville since 1952 for instruction, the new program is the first formal lecture and laboratory course set up by Shell.

A student's course-filled day starts at 8:30 in the morning with a 1-hour lecture. He spends an hour in study preparing homework assignments, then moves into a second morning lecture. After lunch, he divides his time between study periods and work in the laboratory. The school day finally ends at 5:00 pm.

• **Course work**—The first 4 months of the course were devoted to principles of instrumentation (physics, mathematics, and chemistry) and electronics. In physics lectures, for example, the trainees cover electricity and magnetism (10 hours), radiation and light (5), atomic and molecular structure (5), nuclear structure (2), interaction radiation and matter (10), and interaction of charged particles and matter (3). Chemistry lectures incorporate aspects of physical (10 hours), analytical (8), organic (5), and general (7) chemistry. And the mathematics study includes Taylor expansions, Laplace transforms, statistics and errors of measurement, linear differential equations, and complex variables.

The bulk of the course, however, is concentrated on instrument maintenance and installation—100 hours of lecture and 310 of laboratory work. Twenty-five instruments are studied in detail. Fifteen of them are the subject of four lectures each; 10 are the subject of one lecture each.

• **Teaching the context**—There is more to the course than merely teaching the nuts and bolts of modern instrumentation. "What we are trying to do," says Jack Merritt, a Shell Development physicist who helped organize the course, "is to teach the context of the instrument. A wonderful instrument becomes worthless if you don't ask it the right questions."

To know what questions to ask, students spend a lot of time studying basic refinery processes and problems. "A man who is all instrument specialist might lose his perspective," adds another Shell Development instructor. Although the purpose of the new training program is to assure that each Shell refinery will ultimately have two men skilled in instrumentation engineering, the administrators of the program fear overspecialization.

The last ten weeks of the course are spent on automatic control, theory and practice, which is considered a separate segment of the course. The

SHELL'S CURRICULUM

COURSE SUBJECTS	HOURS Lecture	Laboratory
Instrument Maintenance and Installation	100	310
Specific Instruments (70)* 15 at 4 hours each; 10 at 1 hour each		
Application (15)*; Sample Systems (5)*; Maintenance and Trouble Shooting (5)*; Materials of Construction (5)*		
Principles of Instrumentation	100	
Math (35)*; Physics (35)*; Chemistry (30)*		
Electronics	60	195
Automatic Control	80	260
Miscellaneous Items		
Plant Testing	—	40
Tutorial Periods	80	—
Study Periods	125	125
Totals	545	930

* Number of class lecture hours

COURSE SCHEDULE

	4 wks	4 wks	4 wks	4 wks	4 wks	4 wks	4 wks	4 wks	4 wks
		Prin. and Elec.			Inst. Main.		Auto. Cont.		Misc.
8:35– 9:30	Phys.	Phys.	Chem.	Elec.	Lecture		Lecture		
9:30– 9:45	Break	Break	Break	Break	Break		Break		
9:45–10:40	Math.	Math.	Elec.	Inst.	Lab		Lab		
10:45–11:40	Study	Study	Study	Study	Lab		Lab		
11:40–12:20	Lunch	Lunch	Lunch	Lunch	Lunch		Lunch		
12:20– 1:15	Study	Study	Study	Study	Study		Study		
1:20– 2:15	Inst.	Elec.	Lab	Lab	Lecture		Lecture		
2:20– 5:00	Lab	Lab	Lab	Lab	Lab		Lab		

. . . the course relies on student study and do-it-yourself . . .

80 hours of coursework is divided between use of test instruments (10 hours), evaluation of control systems by laboratory test (25), analysis and design of control systems (30), and use of dynamic theory in plants (15).

Instructors are drawn from the instrumentation division staff. At least six men have such a heavy teaching schedule that they have to be considered full time instructors; their teaching loads preclude any other technical activities. On specialized instruments the men who developed the instruments, or who concentrate on the devices, do the teaching.

Surprisingly few of the new audio-visual teaching devices are used in the Shell course. Instead, the administrators have preferred to rely on student study and do-it-yourself. For example, in a typical exercise in the electronics portion of the course, the instructor presents the specifications for a specific device, such as a feedback amplifier, and the students then have to build one.

• **Who's Who**—Students in the course vary in ages and background. Duane Roodzand, from the Anacortes (Wash.) Refinery, is a 1957 ME graduate from the University of Washington. He joined Shell after graduation and has done some project engineering, but he's been in instrumentation for only the past 16 months. H. J. Cannon, representing the Houston refinery, on the other hand, has been with Shell since 1947. A 1938 graduate of the University of Vermont (BS and MS) he was a research laboratory chemist and physicist at the Houston refinery, transferred to instrument engineering in 1954.

The Norco (La.) refinery representative, C. A. Caillet, has spent his entire service at Shell in instrument engineering, is currently senior instrument engineer in Norco's engineering services department. Arthur Towgood from the Montreal Refinery and Theodore Price from Shellburn (Vancouver) have also spent all their service with Shell in instrument engineering. Towgood, a 1953 BSME from the University of British Columbia, previously had worked for du Pont and a consulting engineering firm. Price graduated from the University of Alberta with a BSEE degree in 1953, worked for Canadian General Electric and Progress Electric Ltd. before joining Shell.

F. E. Vidaurri is instrument engi-

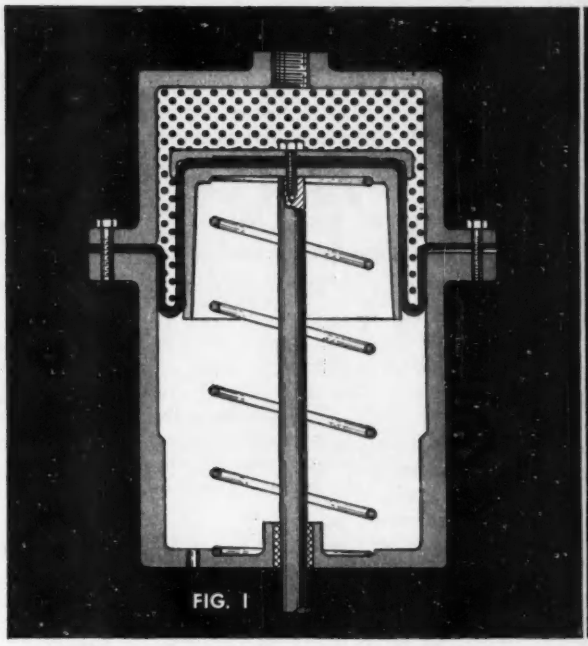


FIG. I

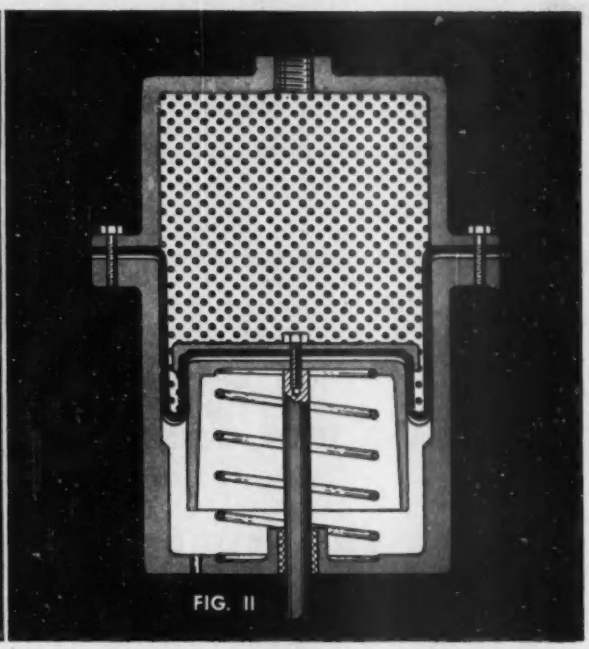


FIG. II

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Fig. I shows how Bellofram Rolling Diaphragm conforms to the piston. Fig. II shows how, as the piston descends under pressure, the Bellofram Rolling Diaphragm *rolls* off the piston's sidewall and onto the cylinder's sidewall in a smooth, continuous, frictionless movement.

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6. **Sensitivity to extremely small pressure changes.**
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11. **Does not require close machine finish tolerances on pistons and cylinders.**
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13. **One hundred stock sizes. Four mounting configurations. Special types and sizes designed to order.**
14. **Excellent temperature stability from —85°F. to 550°F. (from —120°F. to 700°F. in some cases). Wide range of working pressures: 1 inch H_2O to 500 psi (up to 1200 psi in some cases). Effective pressure areas from .028 to 108 square inches. Cylinder bore diameters from .25 to 12 inches. Extended range of stroke (.01 to 12 inches).**

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neer in charge of the instrumentation group at the Wilmington (Calif.) refinery. He had joined Shell after graduating with a BSEE from the University of Texas. Before he transferred to instrument engineering in 1950, he was in the electrical engineering department of the Houston refinery. Another 10-year instrument engineer is James J. Skelly from the Wood River, (Ill.), refinery. A BSEE from Washington University (and MS in 1956 earned at night), Skelly started in Shell's Engineering Design Dept.

The eighth student, Kenneth D. Binham from the Martinez (Calif.) refinery, first learned his electronics in the U. S. Navy, earned a BSEE from the University of Utah in 1958.

—Donald Winston
McGraw-Hill News

Sterlington Computer-Logger Passes Reliability Test

In March 1958, when the Louisiana Power and Light Company installed a digital computer for a monitoring and data logging application, the power company specified that the equipment was to operate 99 percent of the time. Last month, the builder, Control Systems Div., Daystrom Inc., held a press conference to announce that the computer has just completed a six-month period during which the contractual guarantee of 99 percent availability was met.

Certified records, said Daystrom President Thomas Roy Jones, showed that the total downtime attributable to the computer or its ancillary equipment during this 24-hour-a-day run amounted to only 0.25 percent. The solid-state machine at Sterlington has a ferrite core memory, 4,000 transistors, and 7,500 diodes. The ancillary equipment includes electric typewriters, paper tape punches, and digital printers.

Only six failures occurred altogether, and two of these accounted for most of the downtime. None of these failures were due to the typewriters or tape punches, and none of the components in the computer proper experienced a wear-out type failure.

One transistor was accidentally shorted by a voltmeter probe while troubleshooting, and had to be replaced. The downtimes reported included all time from failure to return to complete operation. Otherwise the machine operated on a hands-off, no-maintenance basis during the six-month run.

PROJECT 70,000,000

Since their introduction more than ten years ago, CLARE Type J Relays, with their small size, twin contact design and superior performance, have been first choice of design engineers for applications where component failure is intolerable.

Sensational demand for these relays has resulted in numerous imitations. Similar in appearance and published specifications, many have been represented as "just as good" as the original CLARE Type J Relays.

An independent laboratory has just completed exhaustive tests of CLARE Type J Relays and copies made by other well known manufacturers.

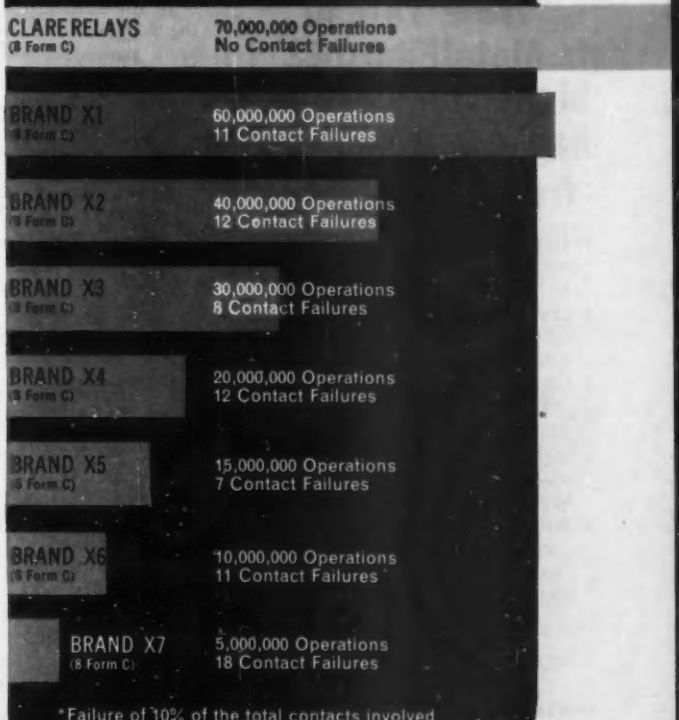
The results are here. Tests of the CLARE relays were discontinued at 70,000,000 cycles . . . *with no contact failure whatsoever.* All the other relay groups showed failure of 10% of their contacts before the end of 60,000,000 cycles (see graph). Some had 22% contact failure at 5,000,000 cycles.

Let us tell you more about this important test. Call or write: C. P. Clare & Co., 3101 Pratt Blvd., Chicago 45, Illinois. In Canada: C. P. Clare Canada Limited, P. O. Box 134, Downsview, Ontario. Cable Address: CLARELAY.

CLARE RELAYS

FIRST in the industrial field

Independent tests* prove There are no copies "just as good" as CLARE type J RELAYS



*Failure of 10% of the total contacts involved eliminated any group from the test. Additional data available on request.

CIRCLE 25 ON READER SERVICE CARD

Electronic controllers for

Electronic Warehouse

. . . combines digital computer for order processing with analog computer controlled sorting system to save a mail-order house $250,000 a year.

Electronic Sorter at work. Operator punches four-digit code number into analog control system, which dumps the goods-carrying trays into the proper tote box. At the end of a 15-min period, when 100 orders have been filled, all tote boxes move to packing area.

MILWAUKEE—In the mail order business, two of the biggest costs are processing the order paperwork and physically putting the orders together. An electronic warehouse installed by the General Merchandise Co., Milwaukee mail order house, has slashed these costs so that company president David Kritzik expects to save $250,000 a year as a result of the installation.

General Merchandise's approach combines two electronic systems with the bulk order picking concept of warehousing. An IBM 650 Ramac digital computer processes all incoming mail orders, provides operating data for the analog computer controlled sorting system, built by Speaker Sortation Systems. Biggest saving is attributed to the electronic sorter which has reduced warehouse personnel from 200 to 20. In bulk order picking, one item, such as gloves, on many orders is picked at the same time, then separated into the proper order. Here's how it works.

• **Into the computer**—when the order arrives at General Merchandise, a clerk converts it to punched cards. The cards are stacked into groups of 400 orders, a number convenient for the sorting system, and fed into the reader of the Ramac installation. Ramac compares each customer's order with information in the machine's memory; it decides whether or not the order can be filled, how much to charge for each item, and where the item is located in the warehouse. Finally, the machine totals up the customer's order and picks the best way of shipping the completed sale—picking the most economical means based on the size, weight, value, and type of merchandise involved.

Ramac turns out a punched card "picking ticket" for each item ordered. On each picking ticket is a code number associating the item with a particular order and a stock number for the piece of merchandise. The 400 orders are divided into four groups, so that 100 orders are filled at one time; the tickets are then arranged in numeric stock number sequence, and turned over to order pickers, men who actually remove the goods from stock. As he selects an item from stock, the order picker attaches the picking ticket to the item with transparent tape, drops it on a conveyor belt which carries the goods to the electronic sorter.

• **Sorter tilts**—At the end of the conveyor, the items are removed by hand and placed in tiltable pans on a sorting conveyor in such a way that the picking slip can be read by a girl operator who sits at the entrance of the sorting loop. As the item passes the operator, she punches the order code number into the analog computer's memory. At the proper time, the sorting system tilts the pan to drop the item into a tote pan. Since one tote pan is assigned for each order, all items on a particular order end up in the same tote pan. When 100 orders are filled (items which are unreadable for one reason or another end up in a 101st pan), the tote pans are conveyed to a packing area where handlers—supplied with boxes, tubes, wrapping paper, string, and tape—prepare each order for shipment.

Running at full capacity, the combined system can process 100,000 items in a 8-hour day. Errors in orders have been reduced to a half of a percent of the items picked. Maximum time for an order to be received,

Electronic controllers for high-performance systems!

The new **GPE Controls** R465 Electronic Controller is built for high performance in every aspect...the result is the **highest degree of dynamic accuracy** possible. Three times as fast as other known control systems, yet comparably priced. With GPE Controls electric transmitters and electro-hydraulic valve actuators, precise control can be maintained at more than 20 cps. Easy, low-cost installation, because high-level d.c. signal makes possible simple unshielded wiring. Instant visual comparison of parallel set-point and process variable indicators.

GPE Controls R465 Electronic Controller features advanced functional design throughout. Controller drawer (left) and manual/automatic station (right) are housed in a dustproof mounting case. Either section may be serviced while the other controls the process. Proportional band, rate, and reset controls are accessible from the front while controller is operating, and are calibrated in logarithmic steps for ease in adjusting to process dynamics.

GPE Controls | A GENERAL PRECISION COMPANY

NEW factual bulletin tells the "how and why" of electronic control. Write for your copy today!

GPE Controls, Inc. (formerly Askania Regulator Company)
240 East Ontario Street • Chicago 11, Illinois

A Subsidiary of GENERAL PRECISION EQUIPMENT CORPORATION

WHAT'S NEW

. . . double memory times input to sortation system so that package is tipped into the correct tote pan . . .

converted to punched card, picked, sorted, and shipped is 2½ hours.

• **Ramac's capability**–For its paperwork processing, General Merchandise has installed three standard disc memory sections. Three hundred information bits are stored to describe each of the 30,000 different stock numbers. The information includes cost to General Merchandise, selling price, description, warehouse location, physical size and weight, and total number in stock. At present the memory is working at half its total capacity; the system could handle 60,000 different items with 300 bits describing each.

• **The analog system**–Speaker's analog sortation system replaces 200 sorters with just 20 operators. The system consists of two oval conveyor loops, located side by side. Each loop is 350 ft long and 12 ft wide.

Fiberglass trays that can be tipped to either side continually move around each loop at a speed of 180 ft per min. On each side of the long leg of the sortation loop are located two conveyors on which are placed tubes or tote pans. Solenoid-actuated levers mounted at intervals on the framework tip the trays, either right or left, to drop the item in the tray into the proper tote pan.

Each of the sorting loops has an analog computer, and two keyboard operators punch in information for each loop. When the operator keys a number into the analog computer, she tells the computer that a package for a given order has entered the system. The point at which the package enters is stored on a rotating magnetic disc which is an analog of the moving endless loop.

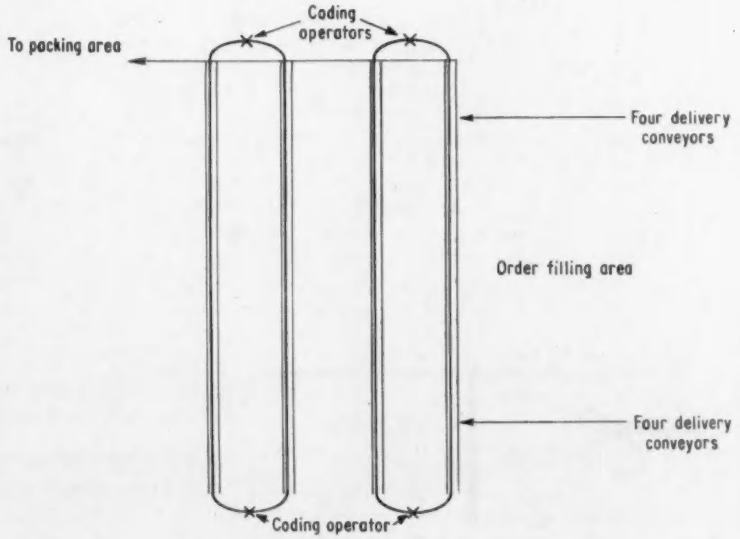
When the package reaches the position corresponding to its four-digit address, a dump signal is generated, actuating the solenoids to tip the tray.

Because 60 packages pass a coding operator every minute, she has only one second in which to enter the four-digit address into the keyboard. Small differences in time could cause the package to dump into the wrong pan.

• **Double memory**–To prevent this, Speaker built a two-part memory into the analog computer. The four digit address first enters a primary thyratron storage. The address number stays there until triggered at an exact instant of time into the secondary neon storage unit which supplies the computer with information. As a result, an exact send-off point exists from which the computer can measure the progress of a tray along the loop.

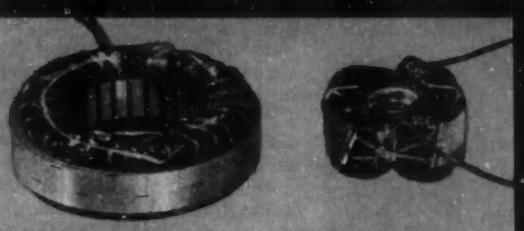
The sortation system has been built almost in the exact center of a 13-acre building. General Merchandise has designed the system for expansion both outward and upward. Additional storage facilities can be built close to the electronic sorter.

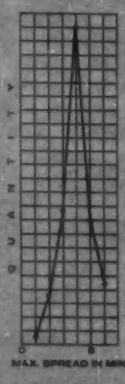
–Bruce Cross
McGraw-Hill News



Sortation loops

SYNCHROS *for* GYRO PLATFORMS by cppc





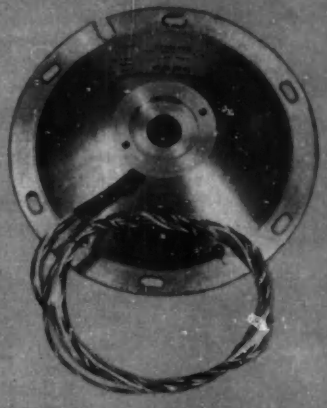
6′ max. error spread Synchro for Gyro Pick-Off

The SG-17- and ST-17- type pancake synchros (SG-18- and ST-18- with housings) are our most standard line for gyro pick-off applications.

These units have been manufactured in large quantity and are readily available for prototype breadboarding. The high accuracies shown on the left are obtainable in standard 26v or 115v units.

Pancake Resolver for Gimbal Mounting

Clifton Precision produces special pancake resolvers for direct gimbal mounting. They were developed for use in cascaded amplifierless resolver systems and have been trimmed for 10K input impedance, 0° phase shift and a constant transformation ratio, with temperature, at 900cy. Accuracies of 4′, perpendicularities of 3′ and nulls of 1mv/v of output or less can be held.



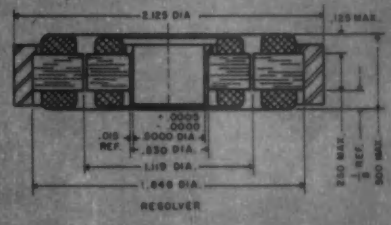
Special techniques maintain concentricity between rotor and stator — thus reducing difficulties commonly encountered in gimbal mountings.

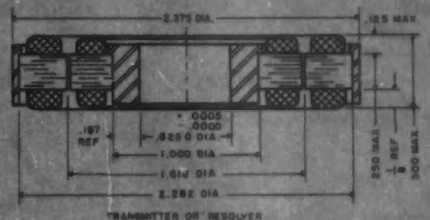
Custom Designed Pancakes

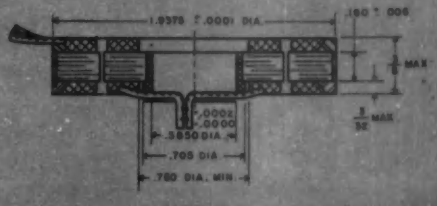
CPPC has developed a number of special pancakes (drawings below) with relatively large bores and narrow stack heights.

Means have been devised to minimize error due to clamping pressures on these thin units.

Special accuracies have been maintained where required. Let us know your needs.







ENGINEERS — Join the leader in the rotating components field. Write David D. Brown, Director of Personnel, Dept. J7

cppc CLIFTON PRECISION PRODUCTS Co., INC.

CLIFTON HEIGHTS, PENNSYLVANIA

Sales Office: 9014 W. Chester Pike, Upper Darby, Pa., HIlltop 9-1200 • TWX Flanders, Pa. 1122—or our Representatives

WHAT'S NEW

Missiles to Medicine

CAPE CANAVERAL—"Cape Canaveral and its environs compose the telemetry capital of the world. How about bringing telemetry into the hospital?" asked an Air Force doctor-colonel, addressing a group of Cape Canaveral missilemen. Col. George M. Knauf, base surgeon and head of the Patrick Air Force Base hospital, added that control techniques had much to offer medicine.

One possibility, said the colonel, was the relay of x-ray pictures over telephone lines. Such a procedure promises tremendous advantages particularly to doctors in rural areas. Col. Knauf envisions a country doctor, stumped with a diagnosis problem, being able to call a specialist at a medical center, transmitting the patient's x-rays, and then having a consultation in a matter of minutes.

Telephone transmission of x-rays has already been proved practical, said Knauf. The reproduction can be made to surpass conventional x-ray films because the received image is monitored more carefully than many films are developed. Dr. Knauf told the group that he planned research in this area at the Atlantic Missile Range.

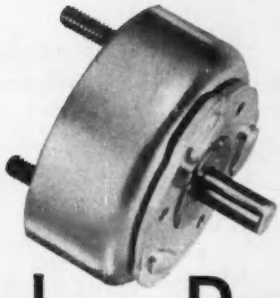
Another intriguing—and technically feasible—application is a central monitoring system for a hospital. Every bed would have a plugboard connected to a central computer. Bedside plugs would permit making a large number of tests by tapping the proper connections; results could be read at the central point. (See p. 19.)

In the field of data reduction, Col. Knauf had some ideas too. If all symptoms, diagnoses, and treatments could be digitized, it would be possible to set up a numerical picture of a patient's condition, then move it to a central point where the best medical brains could diagnose it.

The Air Force doctor described some of the intriguing things seen by medical men on a recent trip to Russia. One was an electrical sleep inducing machine. When a member of the visiting party tried it, the machine put him to sleep in about 10 sec. And he stayed asleep for several minutes after the current was shut off.

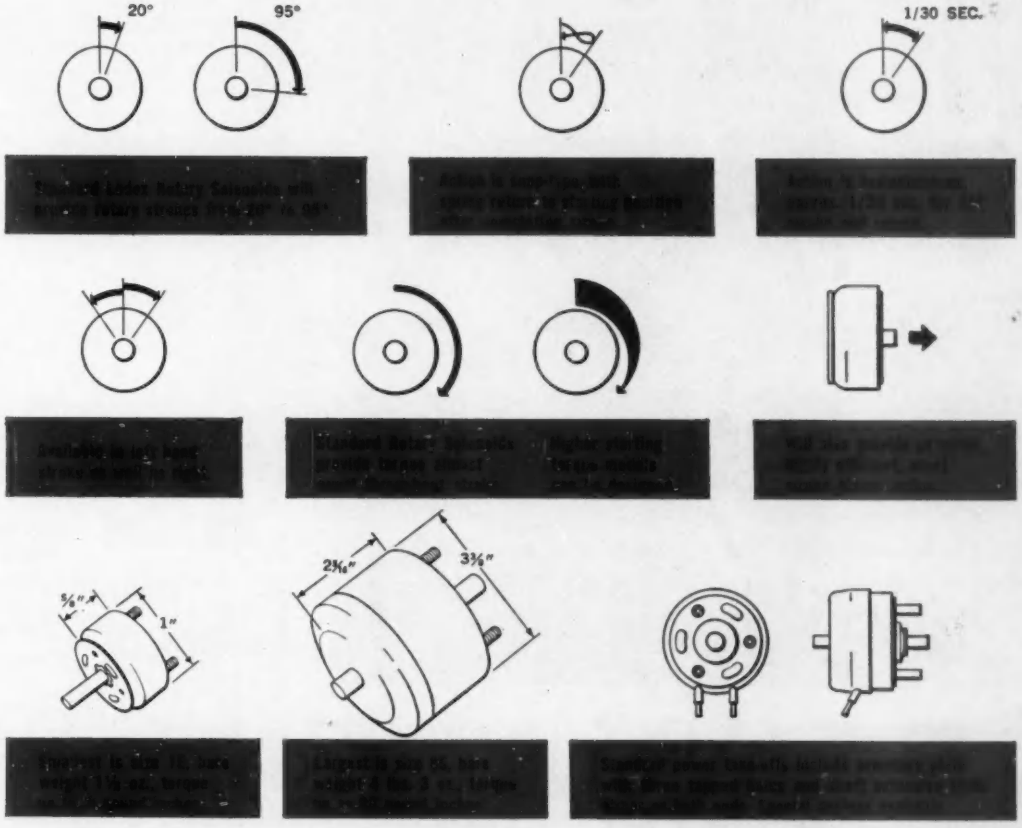
Knauf's eloquent talk has apparently intrigued enough of his audience so that there is interest in forming a medical-electronics division of the IRE on Florida's missile beach.

—Douglas Dederer



Ledex Rotary Solenoid

BASIC INFORMATION



The Ledex Method of actuation and control gives instantaneous high-torque-to-size rotary motion and high-thrust-to-size piston motion, for reliable remote mechanical actuation or remote control of rotary-type switches.

The efficient Ledex Rotary Solenoid is the heart of this method. Available in 8 compact sizes, with operating voltage from 3 to 300 V.D.C. Over 240 stock models ready for immediate shipment. Used in thousands of applications including valves, tape recorders, waveguide switches, sorting equipment, gyrocaging, computers, wireless teletypes, vending machines, typesetters, missile guidance and ground support equipment.

LEDEX

High-torque-to-size rotary motion
High-thrust-to-size piston motion

Other Ledex Method products are Syncramental Stepping Motors, Rotary Stepping and Selecting Switches. Write for Bulletin A-1259, mentioning application, to G. H. Leland, Inc., Dayton 2, Ohio; Marsland Engineering, Ltd., Kitchener, Ont.; NSF Ltd., 31 Alfred Place, London, Eng.; NSF GmbH, Nurnberg, Germany.

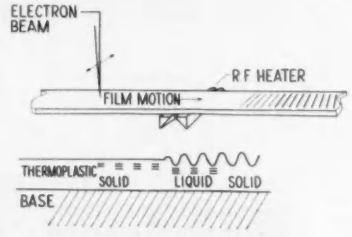
WHAT'S NEW

Thermoplastic Recording Excites Industry

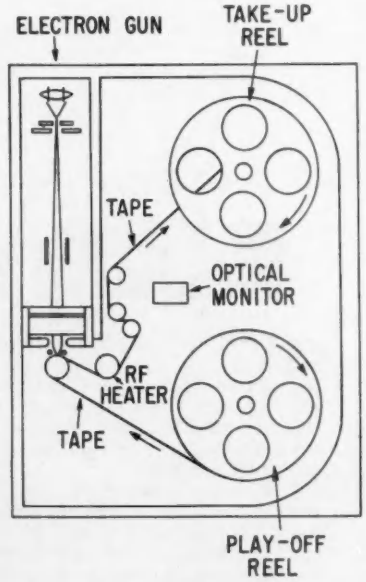
NEW YORK—

When the December issue of the *Journal of Applied Physics* appeared, it carried a short (4 page) apparently innocuous article entitled Thermoplastic Recording by W. E. Glenn of the General Electric Co. (See abstracts, page 172.) But the impact of Glenn's article has not been innocuous. When word of it appeared in newspapers, the value of one magnetic tape maker's stock on the New York Stock Exchange dropped 18 points in two days. Last month GE demonstrated thermoplastic recording to an overflow press conference in New York. It caused even more excitement than the article.

Information can be stored pictorially (see photo p. 34) or sequentially. When stored as binary bits, GE was able to pack 40 million

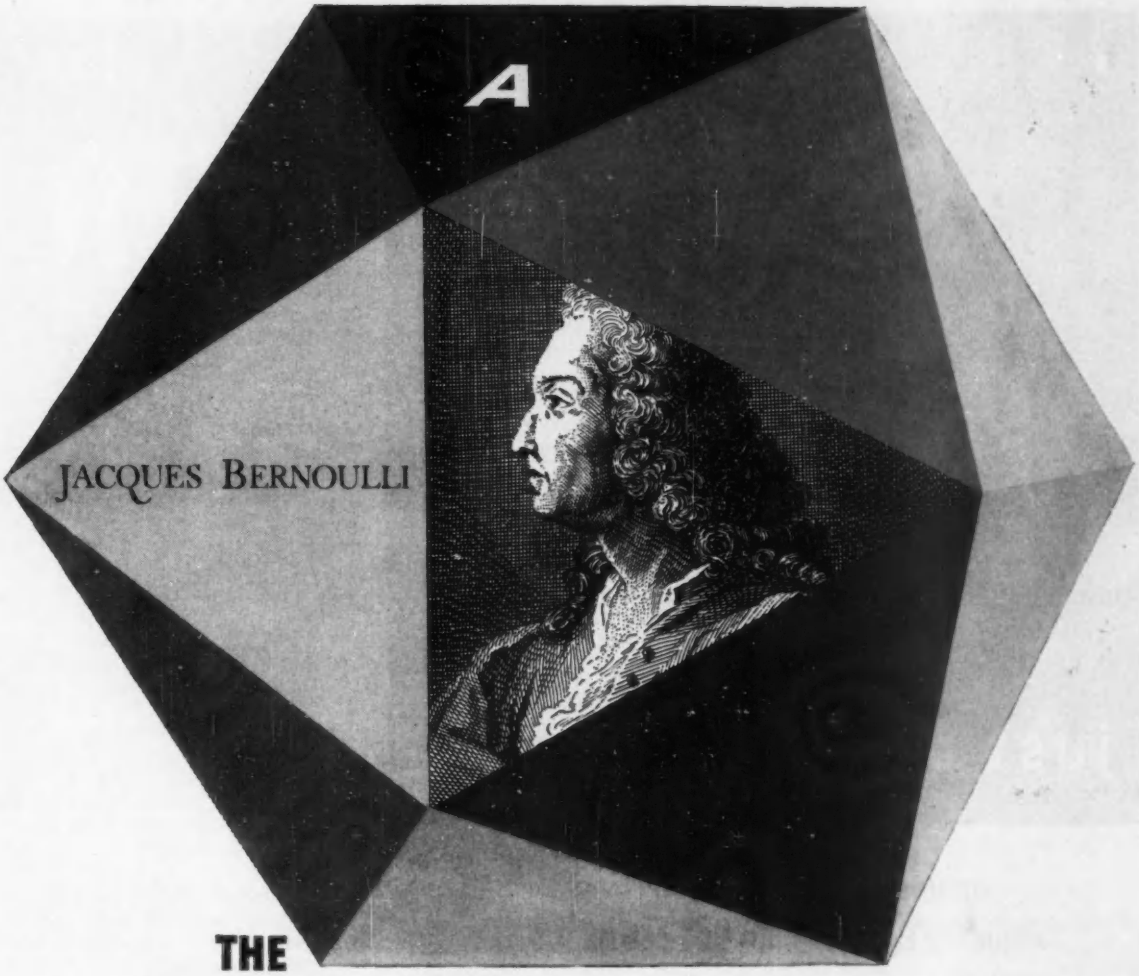


How new technique records data.



Thermoplastic recorder. All gear shown operates in a vacuum.

← CIRCLE 32 ON READER SERVICE CARD



THE WIZARD OF ODDS

He solved a telephone traffic problem two centuries ago

Jacques Bernoulli, the great Swiss mathematician, pondered a question early in the 18th century. Can you mathematically predict what will happen when events of chance take place, as in throwing dice?

His answer was the classical Bernoulli binomial distribution—a basic formula in the mathematics of probability (published in 1713). The laws of probability say, for instance, that if you roll 150 icosahedrons (the 20-faced solid shown above), 15 or more of them will come to rest with side "A" on top only about once in a hundred times.

Identical laws of probability govern the calls coming into your local Bell Telephone exchange. Suppose you are one of a group of 150 telephone subscribers, each of whom makes a three-minute call during the busiest hour of the day. Since three minutes is one-twentieth of an hour, the probability that you or any other subscriber will be busy is 1 in 20, the same as the probability that side "A" of an icosahedron will be on top. The odds against 15 or more of you talking at once are again about 100 to 1. Thus it would be extravagant to supply your group with 150 trunk circuits when 15 are sufficient for good service.

Telephone engineers discovered at the turn of the century that telephone users obey Bernoulli's formula. At Bell Telephone Laboratories, mathematicians have developed the mathematics of probability into a tool of tremendous economic value. All over the Bell System, the mathematical approach helps provide the world's finest telephone service using the least possible equipment. The achievements of these mathematicians again illustrate how Bell Laboratories works to improve your telephone service.

BELL TELEPHONE LABORATORIES

World center of communications research and development

WHAT'S NEW

bits of information on one square inch of thermoplastic material. GE Vice President Guy Suits said the technique could record all the information in one volume of the Encyclopedia Britannica on an amount of thermoplastic tape no bigger than a spool of thread.

• **Military applications first**—GE executives were wary of predicting when thermoplastic recording materials would be available commercially. GE Vice President G. L. Haller thought that U.S. military agencies would have prototype thermoplastic equipment for evaluation sometime in 1960. Some possible applications:

• Identifying radar targets by optical correlation, comparing the received signal with a replica of the transmitted signal to eliminate noise surrounding the received signal.

• Radar, sonar, and infrared displays —permits large screen display of radar and sonar images in a fraction of a second without loss of detail.

• Missile guidance, using map-matching techniques for long range.

• Satellite and space vehicle recorders—capability of gathering huge amounts of information in a relatively small space. One obvious advantage: the system can record pictorial information too.

• Aerial reconnaisance—provides on the spot evaluation of results.

• **Commercial applications**—Most obvious commercial application is for television recording. The new technique may well shape GE's participation in the computer field. One specialist speculated that GE would aim its computer efforts at business data processing.

Pictorial information recorded on thermoplastic. Paper clip on top shows size of frames.

EUROPEAN REPORT

EUROPEAN REPORT

A Look at German Process Control

When a Swiss engineer surveyed the German process industry, he came up with some interesting data on what kind of control equipment is prefered and who uses it.

ZURICH—

German process users are finally switching to electronic and electric control in a big way. This is the conclusion reached by Dr. Fredy Marosky, Swiss control engineer who has just surveyed 100 German firms in the electric utilities, chemical processing, iron and steel, paper, and sugar industries. Asked what kind of controls they used and what kind they planned to employ, the respondents indicated their past and future preferences as follows:

	Present (Percent)	Future (Percent)
Hydraulic	33.0	24.9
Electric (and electronic)	27.3	38.0
Pneumatic	20.8	14.5
Electropneumatic	9.1	11.2
Electrohydraulic	8.1	9.3
Pneumatic-hydraulic	0.2	0.0
Electropneumatic-hydraulic	1.5	2.1

Of the firms surveyed, 74 percent indicated they would be buying new controls within the next two years. Of those with buying plans, 39.5 percent would add controls for plant expansion, 52.2 percent for modernization, 5.3 percent because of a shortage of workers, and 2.7 percent because of other economic reasons.

Over 50 percent of the respondents in each of the electric utilities, iron and steel plants, and chemical processing categories, estimated their individual needs for controls in the next two years at over $50,000. Half of the paper factories envisioned control purchases in excess of $12,000 within the next 24 months.

The survey showed that the electric utility industry is the most intensive user of automatic control systems. Steel and chemical processing were next. In answer to the question "What percent of controllable units are automatically controlled?" results added up this way:

Electric utilities	71.7 percent
Steel works	66.0
Chemical plants	62.5
Sugar factories	58.9
Paper factories	55.4

One other area explored was why users bought the control systems they did. The replies indicate the dominant factors (and the percentage of respondents identifying each factor):

Reliability	50.8 percent
Control accuracy	27.7
Ease of maintenance	17.8
Price	6.3
Manufacturer's service	2.4

Dr. Marosky's survey also shed some light on how German suppliers divide up the process control market. Almost 53 percent of the market is held by six companies: Askania-Werke AG, Siemens & Halske AG, Siemens-Shuckert-Werke AG, Hartman & Braun AG, J. C. Eckardt AG, and Schoppe & Faeser GmbH. The two Siemens organizations are related; so are Hartman & Braun and Schoppe & Faeser.

Nineteen other control companies sell about 30.5 percent of the market. The rest, 16.5 percent, is divided up by 21 German and six foreign control companies.

—Raymond Shah
McGraw-Hill World News

Remote Power Station for Sparse Districts

BRISTOL, ENGLAND—

An official of the British South Western Electricity Board dialed a Princetown number over the public telephone system one day last month, pressed a couple of buttons on an electronic control panel, and an electric generator in Princetown, 100 miles away, began turning. Britain's first remote controlled power station was on the line.

Powered by a land version of the British Proteus, the turbojet engine powering the Britannia airliner, the 3,000-kw generator set could supply electricity to an area serving 10,000 people. Actually the turbine plant will

DU PONT

WIRE AND CABLE ROUND TABLE

You have asked . . .

Q. How are environmental-stress-crack ratings of polyethylene determined? And is there a standard test?

A. There is no universally accepted test for environmental-stress cracking (cracking that occurs when PE is subjected to mechanical stress in the presence of an unfavorable chemical environment). However, one test has become nearly standard for defining this phenomenon.

In this test, a ⅛"x½"x1½" sample of polyethylene is slit to a depth of 0.20" with a razor blade. The sample is then bent with the slit on the outside, and the piece is inserted into a test tube containing a reagent. If the grade of PE being tested is susceptible to environmental-stress cracking, the time required for the cracks to appear is noted. Any cracks signify failure. Usually, many samples are tested at once, and the figures reported show the results as "F50 hours" (time to failure of 50% of the samples).

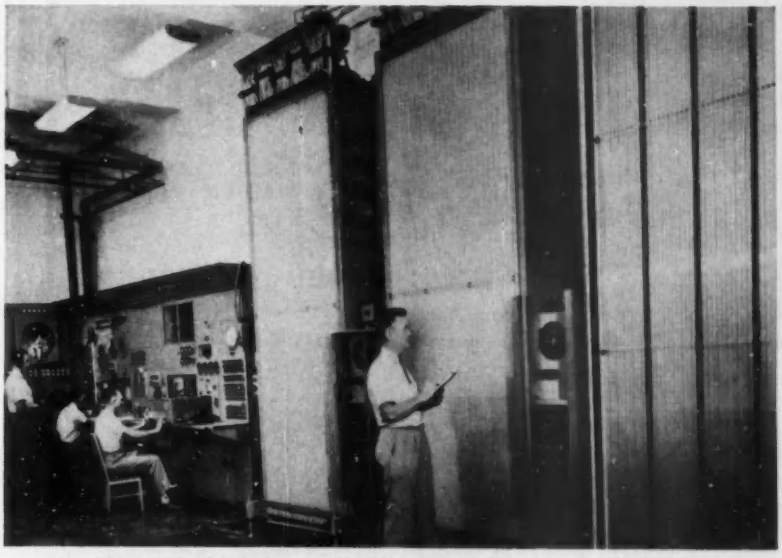
Fortunately for the practical purposes of the user of wire and cable, there is not a confusing myriad of reagents which must be catalogued, nor a wide range of PE's. All polyethylenes are either the high molecular weight, stress-crack-resistant type, or the common insulating type, which is far less resistant to environmental-stress cracking. The former, though somewhat more expensive, is recommended where there is chance of any chemical reagent being present. The latter is suggested only when first costs are unusually important or where the insulation will be protected from chemicals.

Du Pont does not manufacture wire and cable, but supplies thermoplastic resins for insulation and jacketing.

POLYCHEMICALS DEPARTMENT

DU PONT
REG. U.S. PAT. OFF.

Better Things for Better Living . . . *through Chemistry*



Thousands of feet of pneumatic tubing accurately transfer vital test data to one central control room at Air Force research and development center.

Pneumatic tubing of Du Pont ALATHON® saves up to 90% of installation costs

At the USAF's Arnold Engineering Development Center at Tullahoma, Tennessee, pneumatic tubing extruded from Du Pont ALATHON 3C polyethylene resin is relied upon to carry sensitive test results from giant wind tunnels to a central control room for recording. This tubing, sold by The Imperial Brass Mfg. Co., Chicago, under the name Poly-Flo, was selected by the Air Force for many reasons—among them low initial cost and low installation cost.

Pneumatic tubing of ALATHON . . . like Imperial's Poly-Flo . . . is far less expensive than the metal it replaces. However, the dramatic savings are in installation. No flaring tools, wrenches or special tighteners are required for installation. Only a pocketknife is needed to cut the tubing to the proper length, and finger-tightening of the Imperial Poly-Flo fittings assures a foolproof connection.

Thus it is possible to save as much as 90% of installation costs. In one recent documented industrial installation, costs were reduced from $2.10 per foot for installed metal tubing to only 14½¢ per foot for Imperial Poly-Flo tubing. This tubing is impervious to almost all chemicals and solvents, creating extra savings.

Another important point with pressure-sensing instruments is that tubing made from ALATHON does not transmit vibration as some metal tubes will. And the effective temperature range for the use of this pneumatic tubing is -90° to + 175°F.

Why not find out how pneumatic tubing made from Du Pont ALATHON polyethylene resin can save you money in your signal and control applications? Contact The Imperial Brass Mfg. Co., or write: E. I. du Pont de Nemours & Co. (Inc.), Dept. E-2, Room 2507A Nemours Bldg., Wilmington 98, Delaware.

ALATHON® POLYETHYLENE RESINS | **RULAN®** FLAME-RETARDANT PLASTICS | **ZYTEL®** NYLON RESINS

WHAT'S NEW

operate only during peak load conditions. It is the first of a series of remote turbine plants to be established in Britain; a second is being readied at Lynton in Devon.

The control system generates sound and visual information when remotely interrogated by incoming telephone calls from the control desk at Bristol headquarters. The operator can carry out 40 control functions remotely, including start, stop, and throttling operations. Readings of power output, amperage, and voltage are transmitted by telemetry so that the operator can compute the power factor.

After starting the generating set and putting it on load, the operator instructs the remote equipment to disconnect itself from the telephone line. Any change of state at the plant causes the installation to engage its own telephone line and verbally requests the telephone operator to connect the installation with the Bristol control room. The equipment then announces its identity to the control room by voice and offers all control and telemetering facilities. If requests for contact are unheeded, the plant automatically shuts down.

Soviets Plan Search Computer For Chem Compounds

Scientists at the U.S.S.R. Academy of Sciences have started designing a "chemistry information machine" to determine the best chemical compounds to be made from a specified reaction. The Council for Kybernetics expects to feed the machine one fragment of a molecule, to read out the names of all chemical compounds that can possibly be made in a reaction with such a start.

Two groups are working on the computer. One is concerned with the translation of chemical structure forms into linear ciphers so the machine will be able to automatically determine the formula of chemical compounds without the help of chemists. The second group is compiling a dictionary that will list the ciphers in syllables which outline the compounded molecular elements.

●

British Decca Mark X navigational system suffered a serious setback last month when the U.S. Federal Aviation Agency rejected it. FAA, however, will continue research to incorporate some desirable features of the Decca gear.

Millions of Monitors . . . for Hundreds of Applications

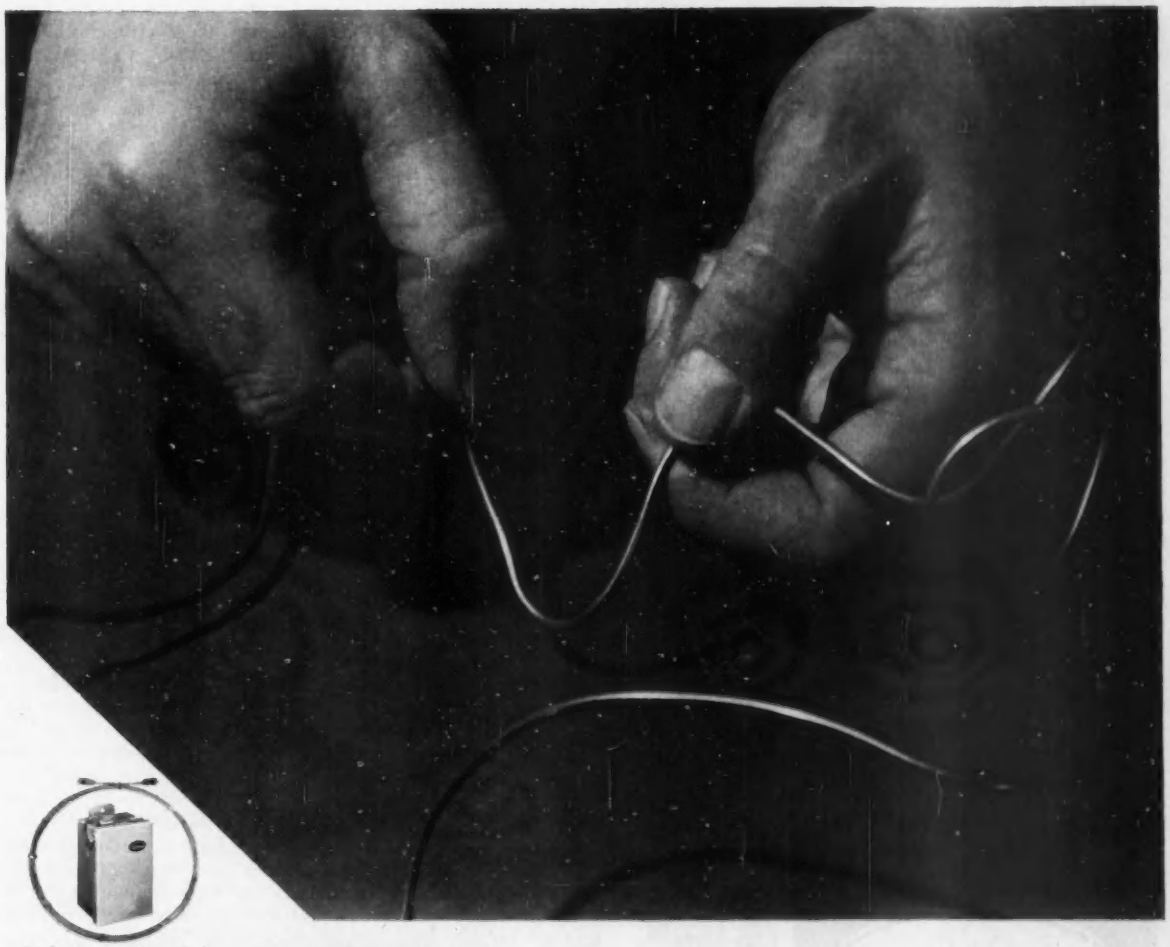
. . . The Fenwal Line Temperature Detector

There are millions of separate, individually distinct temperature "monitors" in a length of the Fenwal Line Temperature Detector's sensing tubing. It's packed with a thermally sensitive eutectic salt compound surrounding a center conductor. *Any point* on the tubing responds instantly and precisely to an undesirable temperature . . . electrically activates alarm and/or corrective control. This *discrete sensing* eliminates the errors inherent in systems based on averaging.

Fenwal Line Temperature Detectors have repeatedly proved their reliability in aircraft and missiles. They are equally applicable in industry: on bearings, in engine test cells, catalyst beds, electric generators, for transformer protection, and elsewhere.

Flexible sensing element mounts easily — forms continuous loop back to compact control unit. Several sections, each set for a different temperature, can be connected in series to operate independently. Rugged design provides constant, fast-acting protection . . . resets automatically.

If you have many points to monitor, chances are a *flexible* Fenwal Line Temperature Detector . . . formed to your exact configuration . . . would help. Talk the application over with a Fenwal Sales Engineer. Write Fenwal Incorporated, 292 Pleasant Street, Ashland, Massachusetts.



Line Temperature Detector

Another example of how **Fenwal** CONTROLS TEMPERATURE . . . PRECISELY

Commerce Sees Instruments Sales Increase

Government forecasts 15 percent gain as result of jumps in capital spending plans.

WASHINGTON—The U. S. Dept. of Commerce foresees a 15 percent rise in sales of scientific and process control instruments in 1960. In its annual year-end forecast and review, the Business and Defense Services Administration signalled out big gains in plant and equipment expenditures by chemical and petroleum refining industries and by the metals industries as prime movers behind the expected jump in sales from 1959's estimated $3.9 billion to $4.5 billion. Biggest gain will accordingly come in process control.

Even though military purchases of aircraft will be reduced in 1960, the agency expects the drop in instrument sales to be offset partially by increased commercial jet plane sales along with a rise in Dept. of Defense spending for missiles, ships and harbor craft, and electronic and communications gear.

• **Industrial sales held over** – A marked increase in capital expenditures over 1959 will take place in 1960. (See also McGraw-Hill Dept. of Economics report, CtE, Dec. '59, p. 45.) Part of the spending this year is the result of plans that had to be delayed as a result of the steel and copper strikes and now add into this year's ledgers. The increases expected in big control-using industries show the booming markets for industrial instruments: chemical and petroleum refining, 18 percent; ferrous and nonferrous metals, a whopping 56 percent; metalworking, 16 percent; other manufacturing, 8 percent; electric and gas utilities, 3 percent; petroleum production and mining industries expect to spend 5 percent less in 1960.

Scientific instrument makers can expect to tap a spending package that is smaller by about $8 million this year. The Federal budget calls for $447 for additional research and development facilities—$92 million less than 1959. But private industry is expected to increase its lab facilities spending by $100 million.

• **Ups and down in DOD**–The Dept. of Defense budget for airplane purchases is $1,069 million less in 1960. This is balanced somewhat for the component instrument makers by a $482 million increase in missiles, a $106 million boost for ships and harbor craft, and $145 million more for electronics and communications.

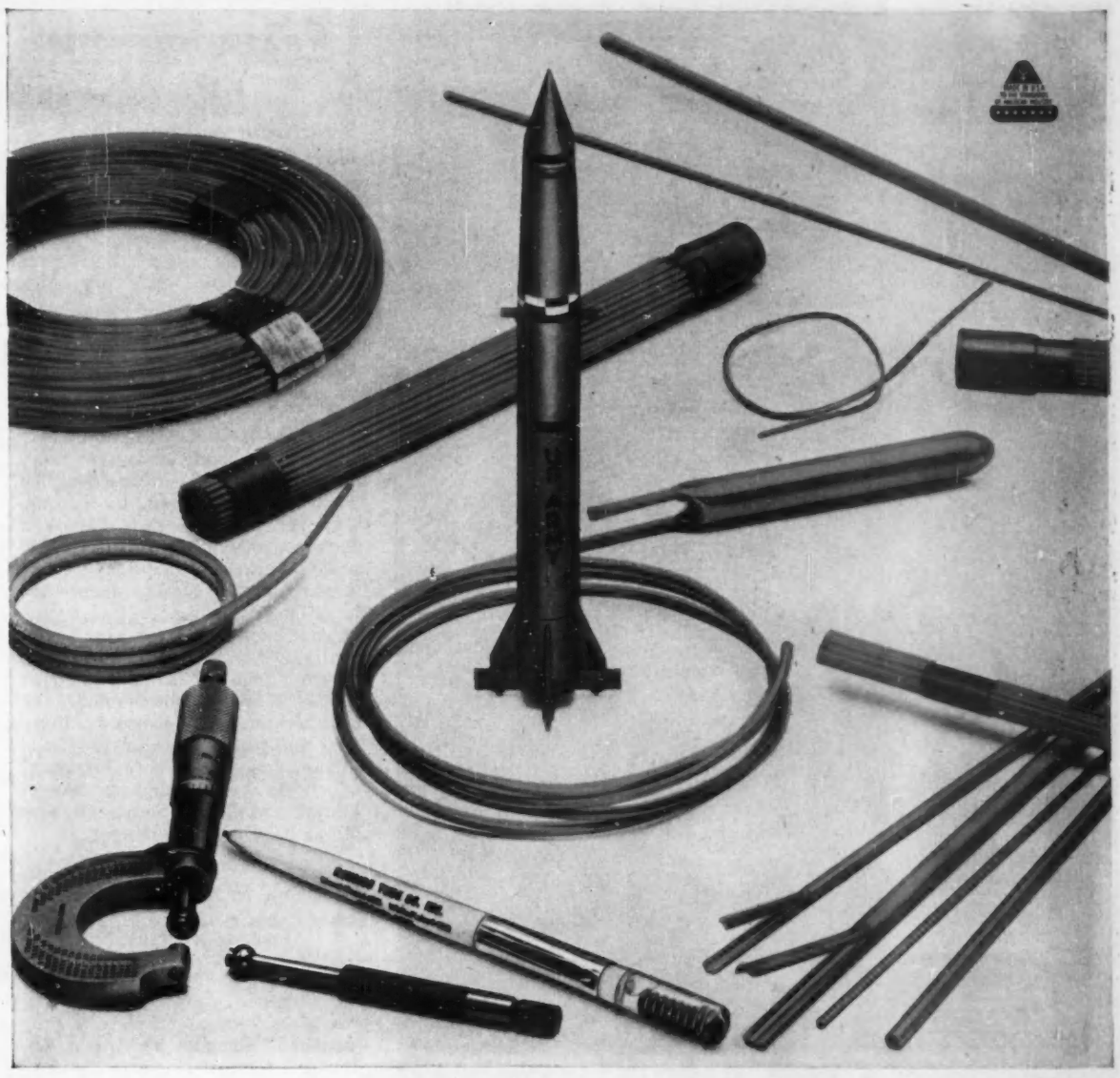
This leaves an over-all decline of $390 million in these four major DOD budget areas. It may be taken up elsewhere in the government by the Federal Aviation Agency's stepped up spending for commercial airport facilities. Other good signs for this field are the 12 percent increase in capital spending by the transportation industries and a 9 percent rise forecast for commercial businesses' funding.

• **A good year in '59**–The National Science Foundation's figures for 1959 show the Federal Government's obligations for additions to research and development facilities should total $539 million. This is a $138 million increase over 1958. Private industry is estimated to have spent $160 million for new lab installations in 1959–30 percent more than 1958. These figures bear out the estimated 20 percent scientific instrument sales rise for '59.

Capital expenditures were down from estimates made early in the year as a result of the steel and copper strikes, but a larger share of the money was spent for modernization–particularly in the chemical industry. As a result, industrial instrument sales should log a 15 to 20 percent gain.

Component instrument manufacturers saw DOD spending in the four biggest areas (see above) rise in total by $383 million; airplanes buying alone was down by more than twice that amount. But money spent for commercial traffic aids showed a $36.5 million rise. Private outlays in communications and transportation are estimated up $877 million and commercial business, about $845 million. The result should be a 20 to 25 percent increase for component sales.

In total, scientific and process control instruments are expected to show a 20 percent increase over 1958's sales of $3,251 million.



EVER REALLY EXPLORE INNER SPACE?

Inner space of copper Capillary and Restrictor Tubing, that is? Especially that used for instrumentation and controls? Kensico recently asked an independent consulting service to explore the inner space of its small-diameter, *precision-drawn* tubing in comparison with leading competitive products. Some mighty revealing discoveries were made by using *photomicrography!* Interested control engineers may obtain a set of these photomicrographs—or Free Flow Charts and engineering consultation—by simply calling, writing or wiring ...

We also make hard and soft copper water tube . . . copper air conditioning and refrigeration tubes . . . copper tubing for propane gas lines, heat exchangers, automotive and industrial applications.

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Kensico Tube

COMPANY INCORPORATED, MT. KISCO, N. Y.

WHAT'S NEW

Swartwout Autronic Div. Now Part of Crane Co.

The Swartwout Co.'s Autronic Div., pioneer electronic control system builder, has been absorbed by the Crane Co., the nation's largest supplier of industrial valves and fittings.

The acquisition (for cash, amount not revealed but estimated at several million dollars) paves the way for Crane to offer complete automatic valve system packages to the chemical and petroleum industries. Up to now Crane has had to buy its controls.

Crane has been anxious to move into the systems engineering field, has wanted a head start in the controls end of it. With the other division of Swartwout (Ventilators) sold to another buyer several months ago, Crane was in a position to snap up an established control maker.

The Chicago valve company has recently gone through an internal shakeup under Chairman Thomas Mellon Evans, expansion-minded industrialist who took control last April after threatening a proxy fight. Crane will continue Swartwout's operations under the current administration of Kenyon and Charles Swartwout, sons of founder Denton Swartwout.

Motorola in Aviation Field; Buys LearCal Div.

CHICAGO—

Purchase of the LearCal Div. of Lear, Inc. puts Motorola, Inc. in the aviation electronics business for the first time. The deal involved an undisclosed number of Motorola common shares.

LearCal has been making airborne communication and navigation equipment and autopilots for light aircraft. Its 1959 sales are estimated at about $8 million (9 percent of Lear's estimate total). Lear will continue to manufacture commercial and military autopilots and flight control and instrumentation equipment.

Motorola has for the last several years been searching for companies to acquire or merge with to diversify. The company has eyed aviation electronics for some time. The leading independent producer of auto radios, the company markets home television and radio equipment, mobile two-way commercial radio, and microwave gear, is also heavily engaged in transistor research and production.

Lear Board Chairman Dr. William P. Lear said that "the transfer will

LOW LEVEL INPUT AMPLIFICATION

- *1,000,000:1 rejection ratio at 60 cps*
- *floating input*
- *isolated output*

IN 2 NEW SANBORN CHOPPER AMPLIFIERS

INDIVIDUAL SET-UPS

portable, self-contained unit amplifier

The Model 350-1500 Low Level Amplifier provides extremely versatile measurement of low level signals through use of two interchangeable plug-in circuits — one for thermocouple applications, another for DC strain gage work (other plug-ins now in development). Floating input and isolated output make the 350-1500 useful when signal measurements are made in the presence of large ground loop voltages. The 10-1/2" high x 4-3/16" wide 350-1500 may be used individually with its own power supply to drive a 'scope, meter, optical element, etc. or as a preamplifier in 6- or 8-channel 350 series recording systems.

MULTI-CHANNEL INSTALLATIONS

8-unit 7" high modules for "850" series direct writers

Compact Model 850-1500A Low Level Preamplifiers are economical, space-saving units for large installations such as aircraft and missile development and test facilities where many recording channels are used to monitor strain gage and thermocouple outputs. Required 440 cps chopper drive voltages can be supplied for up to 16 channels with the *Model 850-1900 MOPA*.

SPECIFICATIONS

	350-1500	850-1500A
Sensitivity	20 uv input for 1 volt output, or 10 chart div. with Sanborn recorder; X1 to X2000 attenuator	100 uv input for 1 volt output, or 10 chart div. with Sanborn recorder; X1 to X200 attenuator
Input	Floating, can be grounded	
Input Impedance	100,000 ohms	200,000 ohms
Output	Floating or grounded (independent of input)	
Output Impedance	350 ohms	
Output Capabilities	±2.5 volts across 1000 ohm load	
Bandwidth	DC – 100 cps (3db)	
Linearity	±0.1% of full scale	
Common Mode Performance	120 db for 60 cps and 160 db for DC with 5000 ohms unbalance in source	
Noise	2 uv peak-to-peak over a 0 to 100 cps bandwidth	
Drift	±2 uv for 24 hours	
Gain Stability	±0.1% for 24 hours	

(specifications subject to change without notice)

Complete specifications and application data are available from Sanborn Sales-Engineering Representatives in principal cities throughout the United States, Canada, and foreign countries.

SANBORN COMPANY
INDUSTRIAL DIVISION
175 Wyman Street, Waltham 54, Mass.

CIRCLE 43 ON READER SERVICE CARD

WHAT'S NEW

enable Lear, Inc. to appreciably expand its activity in the air transport, industrial electronics, and solid-state physics fields and give even greater emphasis to its military missile activities, while retaining an investment interest in the products which it developed." Lear said he was an "early friend and first chief engineer" of Paul Galvin, Motorola's founder, who died last November.

Hamilton Standard Acquires Half of Microtecnica, Rights To Zeiss Process

Bouncing back from two recent defense contract cuts (F-108, CtE, Dec. '59, p. 50 and B-70, CtE, Jan. '60, p. 95), Hamilton Standard Div. of United Aircraft Corp. has drawn on European know-how for the next steps in its diversification program. It has purchased a 50 percent interest in Microtecnica, Inc., control firm of Turin, Italy, and has acquired the North American rights to an electron beam machining and welding process developed by the Carl Zeiss Foundation of West Germany.

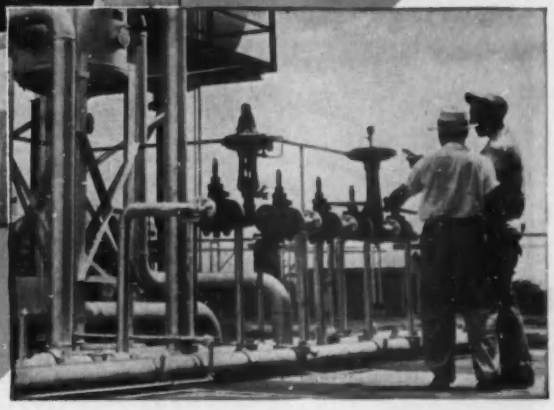
Microtecnica was founded in 1928 by its present managing director and president, Agostino D. Derossi. Its main products today are marine and aviation navigational instruments, optical and mechanical testing instruments, and servomechanisms. Microtecnica's facilities received a beating during World War II, but the company staged a comeback keyed to production of motion picture projectors. There are now 2,500 employees.

Terms of the agreement include provisions for licenses for the Italian company to produce many of HSD's jet aircraft equipment for the European Common Market. No licenses have been granted for HSD manufacture of Microtecnica developments, but a Hamilton spokesman said that this arrangement might come about.

The German machine which HSD will distribute, now known as the Hamilton-Zeiss electron beam machine, can perform machining or welding operations on the hardest materials impossible with any other process. It can cut holes finer than a human hair through, or surface-treat, melt, or weld virutally every known material.

Developed in the postwar years by the Carl Zeiss Foundation of Oberkochen, the process has been available in the U.S. through Electrona, Inc. of New York City. The tech-

You Can Count On These Engineering And Field Services When You Buy BS&B CONTROLS!



5 "Plus" Factors Are Your Guarantee Of Satisfaction With BS&B!

1 Sales Engineering: BS&B Sales Engineers and Representatives are strategically located throughout the United States, Canada and Latin America to assist you with specifications, operation and maintenance problems involving BS&B Controls.

2 Application Engineering: BS&B Controls Application Engineers are specialists in instrumentation and process control applications, can analyze your control systems from the standpoint of over-all plant design, operation and maintenance requirements.

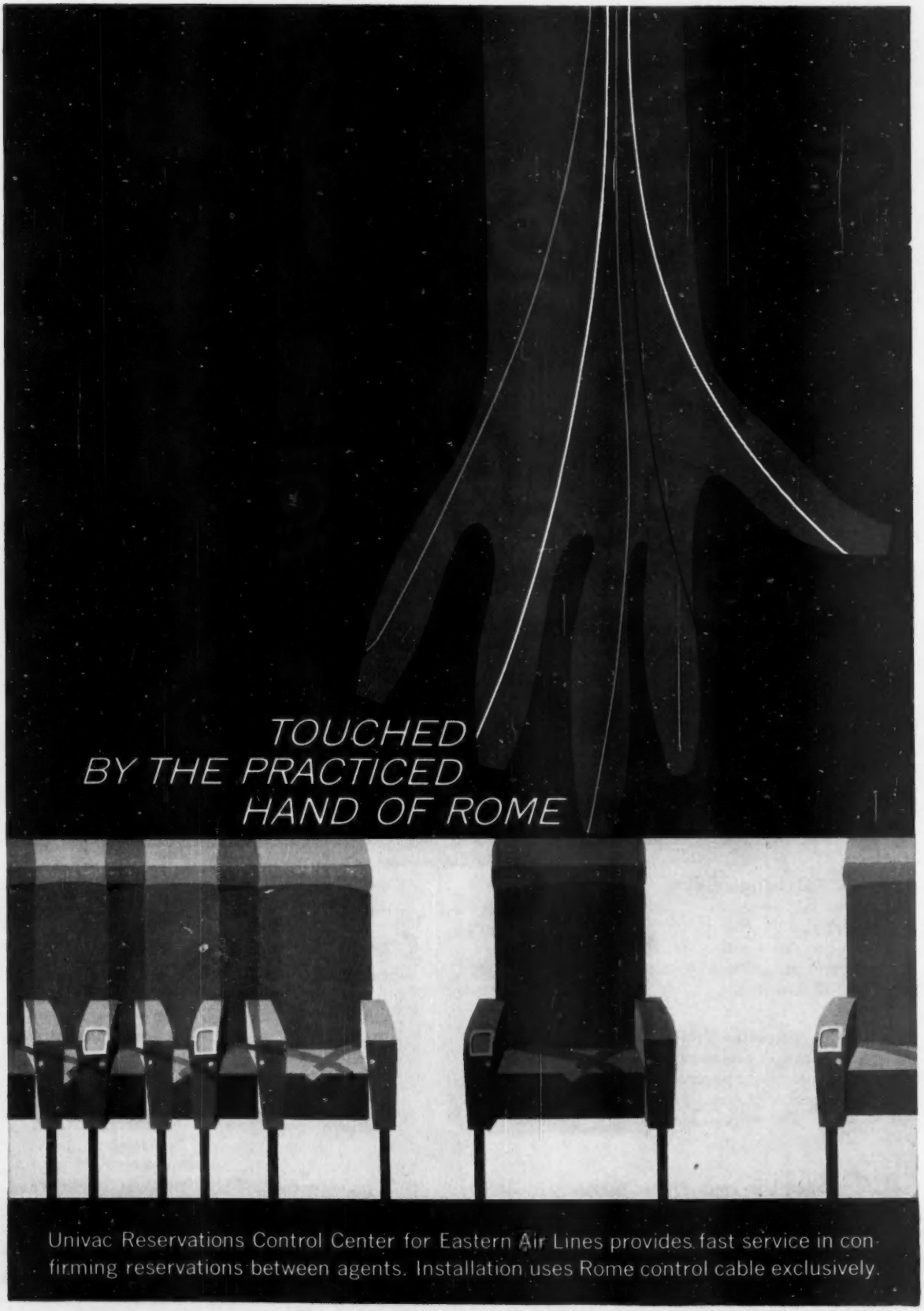
3 Start-Up and Field Service: A BS&B Engineer will assist you in equipment calibration and control point settings on BS&B Controls during your start-up period, and will service any BS&B equipment after your plant is put "on-stream".

4 Research, Development and Testing: BS&B has one of the industry's most complete and up-to-date laboratories where control equipment is constantly undergoing development and actual test data are utilized to offer a *specific* solution to your *specific* controls problem.

5 Branch and Central Stocks: Standard BS&B Controls items and replacement parts are stocked at strategic locations to meet your field replacement and emergency maintenance problems.

BLACK, SIVALLS & BRYSON, INC.

Controls Division, Dept. 4-ES2 7500 East 12th Street Kansas City 26, Missouri



Univac Reservations Control Center for Eastern Air Lines provides fast service in confirming reservations between agents. Installation uses Rome control cable exclusively.

WHAT'S NEW

nique has demonstrated major improvements in welding atomic reactor cores and milling subminiature electronic components in several installations in this country.

The welding version is leased for $25,000 a year, the drilling and milling unit for $35,000 per year with relay controls and $42,500 with magnetic tape controls. The tape-controlled unit will be available by the middle of 1960.

Hamilton Standard will begin manufacturing the equipment at its Windsor Locks, Conn., plant in 1960. Sales will be handled by a new Hamilton-Electrona, Inc.

709's at $315 an Hour—
—But Not the Rush Hour

The first two of IBM's new Datacenters are open to customers—customers who have $450 an hour to use a 709 computer. Announced last fall (CtE, Sept. '59, p. 50), 24 such Datacenters were to provide time on the solid-state 7070 by the hour; users supply their own programmers and operators—only machine time is sold. First center was to open in March.

But IBM has rushed ahead to keep up with other computer makers and consultants who are offering similar arrangements (CtE, Nov. '59, p. 54). The first six Datacenters will have the more available (and more powerful) 709 machine. The first two $2.5 million systems are located at IBM's plant in Poughkeepsie, N. Y., and in the new Time & Life Building in New York City's Rockefeller Center. Originally announced rate for the 7070 centers was under $300 an hour. Rates for the 709 centers will be reduced in the off-hours after 6 P. M. to $315.

New Consulting Firm To Advise on Reliability

Reliability Control Engineering is the name of a new consulting company formed in Ridgewood, N. J., to advise smaller components manufacturers on the reliability requirements of weapon system and space vehicle projects. Founded by Adoph Warsher, the new outfit will also engage in basic research and development in reliability measurements.

Warsher was formerly manager of Bendix Aviation Corp.'s reliability engineering at its Eclipse-Pioneer Div. and chairman of Bendix's Inter-Divisional Reliability Committee.

Lockheed Forms New Company To Include LEAD, Stavid

—BURBANK, CALIF.

A reorganization at Lockheed Aircraft Corp. is a step towards diversification and expansion of LAC's penetration of the various electronic markets. A new company, Lockheed Electronics Co., has been formed out of two divisions: Stavid Engineering, Inc. and the Lockheed Electronics and Avionics Div. (see LEAD story, CtE, Oct. '59, p. 50).

The recently acquired Stavid Engineering becomes the Stavid Div. in Plainfield, N. J.; LEAD, which was formed last March, becomes the Newport Div. of Newport Beach, Calif.

Former Stavid president, David F. Sanders, will become LEC president, and M. Carl Hadden, Lockheed vice-president and LEAD general manager, will become vice-president of LEC and general manager of its Newport Div. Stavid's executive v-p, Frank J. Reynolds, will be LEC v-p and general manager of the Stavid Div.

Lockheed President Courtland S. Gross claims that "formation of LEC will strengthen our over-all effort, make the most effective use of our people and facilities, avoid major divisional overlapping, permit greater technical specialization, and simplify our marketing job." A prime goal of the move is to increase the civilian portion of the company's business.

Telecomputing Adds Another; Phoenix New Subsidiary

Newest addition to the Telecomputing Corp. skein is Phoenix Engineering and Mfg. Co., a manufacturer of precision missile, aircraft, and electronic parts.

The already well diversified Los Angeles buyer is strengthening its fiscal image following recent events (CtE, Jan. '60, p. 64) that had clouded its image in the eyes of the financial community. The terms of the acquisition were not disclosed, but the transaction did not involve the issuance or exchange of any TC stock.

Phoenix (located in the Arizona namesake city) had 1959 sales of $1 million; TC's president, William Whittaker, predicts a 50 percent increase to more than $1.5 million next year. The firm will be a subsidiary; Harold C. Olsen, who founded the company in 1950, will continue as president. Donald A. Hendricks, a former plant manager of TC's Whittaker Controls Div., will be new vice-president and general manager.

(Continued on page 165)

SIZE 8

SYNCHROS · SERVO MOTORS · MOTOR TACH GENERATORS

400 Cycle: Many for 125°C operation . . . Higher for special applications

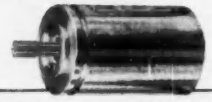
Many Immediately Available From Stock in Small Quantities

SIZE 8  SYNCHROS

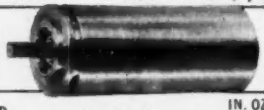
Highly Stable. Minimum Error Variation from −55°C to +125°C

OSTER TYPE	CLASS	INPUT VOLTAGE	INPUT CURRENT AMPS	INPUT WATTS	OUTPUT VOLTAGE	PHASE SHIFT (° LEAD)	ROTOR RESISTANCE (OHM)	STATOR RESISTANCE OHMS	Z_{ro} OHMS	Z_{so} OHMS	Z_{rss} OHMS	NULL VOLTAGE (MV)	MAX. ERROR FROM E.Z. (MIN.)
4253-01*	LZ-CT	11.8	.087	.21	23.5	9.0	157.0	24.0	212+j722	28+j119	263+j69	30	±7
4269-01*	Diff	11.8	.087	.21	11.8	9.0	35.0	24.0	37+j139	28+j124	47+j13	30	±7
4273-01**	XMTR	26.0	.100	.54	11.8	8.5	34.0	12.0	48+j255	12+j45	82+j31	30	±7
4277-01*	HZ-CT	11.8	.030	.073	22.5	8.5	316.0	67.0	500+j1937	79+j350	594+j182	30	±7
4261-01**	Resolver	26.0	.043	.39	11.8	15.0	162.0	22.0	208+j612	34+j159	243+j77	30	±7

*Stator as Primary **Rotor as Primary

SIZE 8  SERVO MOTORS

OSTER TYPE	RATED VOLTAGES	Z = R + jX	IN. OZ. STALL TORQUE	RPM NO LOAD SPEED	WATTS PER PHASE	GM. CM. ROTOR INERTIA	LENGTH IN. MAX.	WEIGHT OZ.	T/I RATIO RAD/SEC²
5004-01	26V 26V	288 = 226 + j 176 294 = 238 + j 174	.15	6200	2.0	.47	0.863	1.2	22,500
5004-02	26V 36V	288 = 226 + j 176 526 = 409 + j 332	.15	6200	2.0	.47	0.863	1.2	22,500
5004-03	26V 40V	288 = 226 + j 176 715 = 582 + j 415	.15	6200	2.0	.47	0.863	1.2	22,500
5004-09	26V 40V	230 = 190 + j 131 519 = 399 + j 332	.20	6200	2.5	.47	0.863	1.2	30,000

SIZE 8  MOTOR TACH-GENERATORS

OSTER TYPE	RATED VOLTAGES	Z = R + jX	IN. OZ. STALL TORQUE	RPM NO LOAD SPEED	WATTS PER PHASE	GM. CM. ROTOR INERTIA	LENGTH IN. MAX.	WEIGHT OZ.	T/I RATIO RAD/SEC²	GENERATOR VOLTAGE	INPUT WATTS	OUTPUT VOLTS PER 1000/RPM
6204-01	26V 40V	230 = 190 + j 131 519 = 399 + j 332	.20	6000	2.5	.65	1.728	2.5	21,800	26	2.5	.25
6204-03	26V 26V	230 = 190 + j 131 230 = 190 + j 131	.20	6000	2.5	.65	1.728	2.5	21,800	26	2.5	.25

Oster®

The Size 8 400 Cycle Servo Motor Tach Generators listed above have 150° max. cont. frame temperature, 110 MA input current, ±5° phase shift and Null Voltage (Total R. M. S.) of 15 millivolts.

OTHER PRODUCTS INCLUDE:

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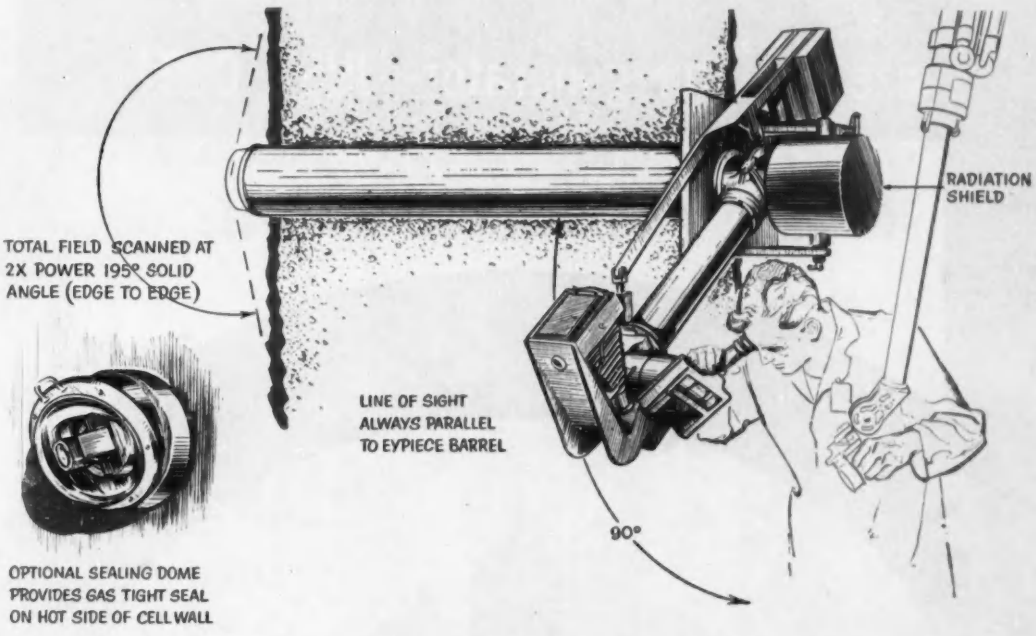
Engineers For Advanced Projects: Interesting, varied work on designing transistor circuits and servo mechanisms.
Contact Mr. Robert Burns, Personnel Manager, in confidence.



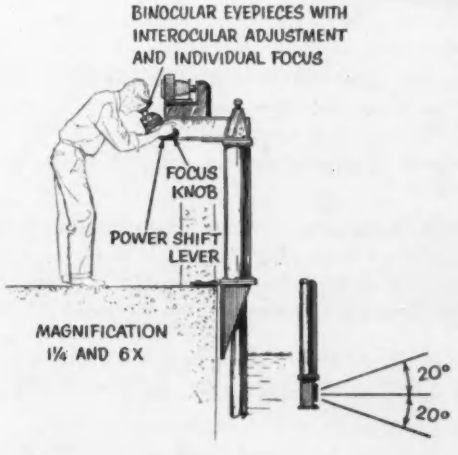
Kollmorgen instruments are bridges between the eye and the invisible

Danger of radioactive contamination prevents a contiguous close look at many vital operations and processes. Kollmorgen remote viewing equipment lets you see with complete safety and maximum freedom of observation.

Kollmorgen designs and manufactures more remote viewing and inspection equipment for use in "hot" labs and reactors than any other company. Wall periscopes, underwater periscopes, microphoto periscopes, continuous strip fuel-inspection cameras and similar equipment by Kollmorgen have been installed in almost every major nuclear installation on the North American continent.

Kollmorgen is foremost in the design, development and manufacture of mechanically and electronically controlled optical instruments and systems for industrial and defense applications.

Write on your company letterhead for a copy of our new twenty-four page facilities brochure. Your copy will reach you by return mail.



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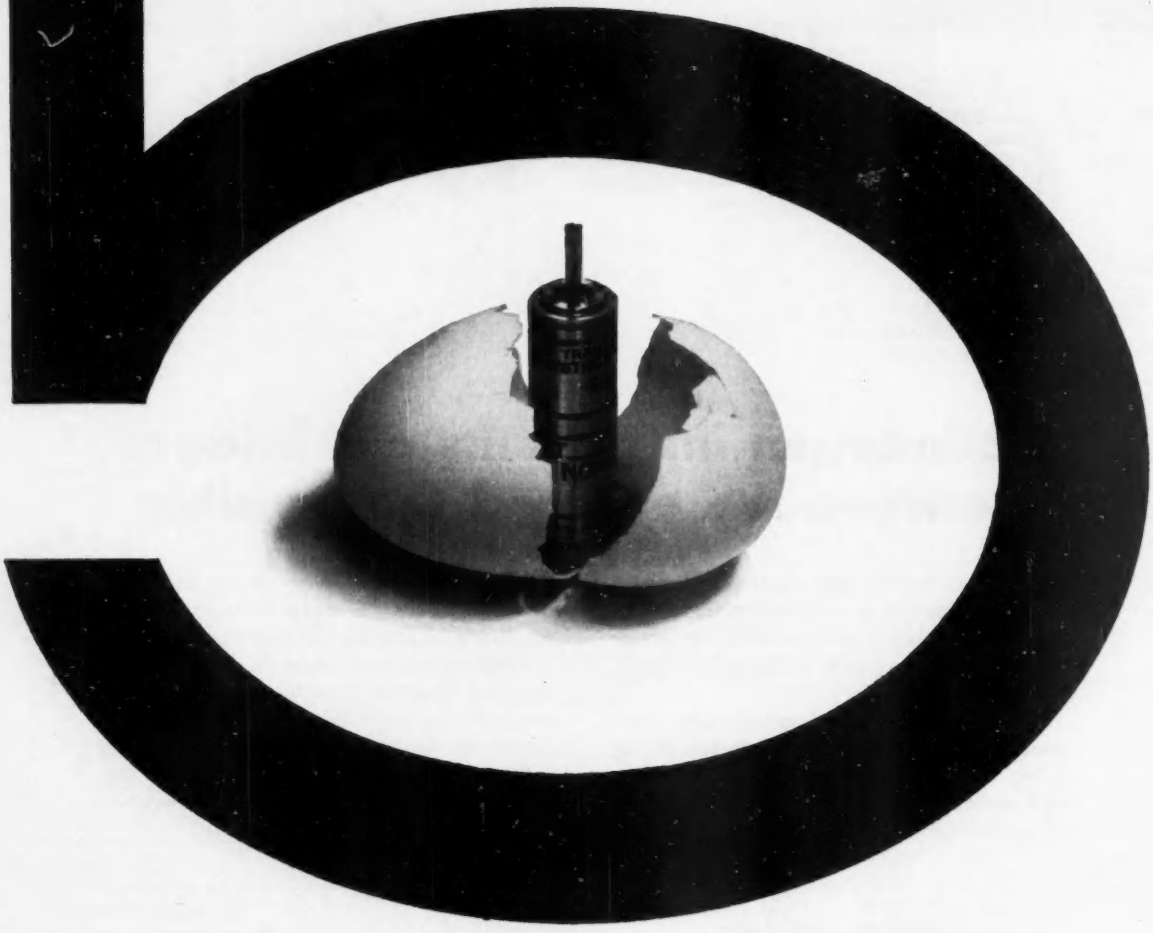
WESTERN TECHNICAL REPRESENTATIVES—
COSTELLO & COMPANY, LOS ANGELES, CALIFORNIA.

CIRCLE 49 ON READER SERVICE CARD 49

size 5 motor generator—JUST OUT!



Here it is . . . the smallest—and lightest—motor generator combination in the industry today. And you can get it with the new Size 5 Gear Train, too. Weighing a mere 1.1 oz., the Size 5 develops a minimum stall torque of 0.11 oz. in. and has a free speed of 10,000 rpm. Units are available for 400 cycle operation with 26 or 33 control phase winding. The control phase is split for operation directly with transistor amplifiers.

Write for complete specifications. And be sure to get all the details on our new synchro line. Daystrom Transicoil Division, Worcester, Montgomery County, Pa. Phone: JUno 4-2421.
In Canada: Daystrom, Ltd., 840 Calendonia Rd., Toronto 18, Ont.
Foreign: Daystrom International Division, 100 Empire Street, Newark 12, N.J.

DAYSTROM
TRANSICOIL DIVISION

Ask Your *FISHER/MAN* How To

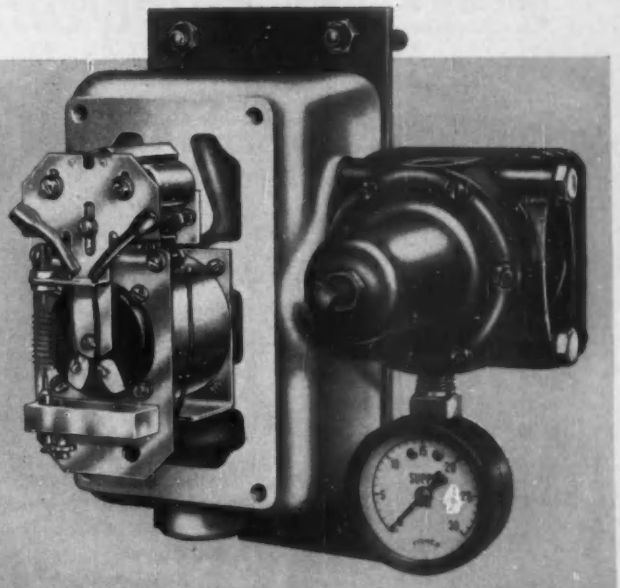
SPEED THE INPUT SIGNAL to the CONTROL VALVE

FISHER

TYPE

543

ELECTRO PNEUMATIC TRANSDUCER



Available with or without a pneumatic valve positioner

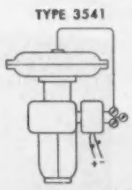
Here's an electro-pneumatic transducer developed for use in electrical control loops where the final control element is pneumatically operated. Explosion proof design makes it ideal for use under hazardous conditions. Input signals may range from 1 to 5 ma. through 10 to 50 ma.... output from 3 to 15 psi through 6 to 30 psi. Built-in volume relay permits direct operation of the pneumatic actuator from the Transducer. No extra relays or boosters needed. Relay can be serviced independent of electrical assembly. Unit is completely reversible by reversing input leads and rezeroing.

If you want additional information on the Type 543 Electro-Pneumatic Transducer write Fisher Governor Company.

TYPICAL CIRCUITS		
Input Current	Load Requirements of Controller	Actual Internal Resistance of Transducer
1 to 5 ma dc	3,000 ohms maximum	2,500 ohms ±125 ohms
1 to 5 ma dc	12,000 ohms ± .5%	12,000 ohms ± 50 ohms
10 to 50 ma dc	500 ohms maximum	57 ohms ± 4 ohms

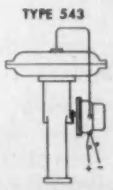
PERFORMANCE DATA	
Linearity	1% of full range
Air Consumption Rate	2 SCFH with 15 psi output pressure
Resolution Sensitivity	.05% of input range
Frequency Response	Complete frequency response data with Fisher topworks available

TYPE 3541



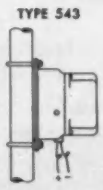
Electro Pneumatic Controller Mounted on Control Valve

TYPE 543



Transducer Mounted on Control Valve

TYPE 543



Transducer Mounted on Stand Pipe

IF IT FLOWS THROUGH PIPE ANYWHERE IN THE WORLD... CHANCES ARE IT'S CONTROLLED BY...

FISHER GOVERNOR COMPANY

Marshalltown, Iowa / Woodstock, Ontario / London, England

CONTINENTAL EQUIPMENT CO. DIVISION, Coraopolis, Pennsylvania

FISHER Controls

SINCE 1880

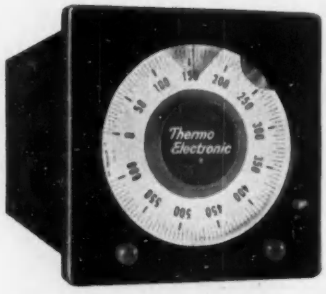
Design does make a difference

in the NEW Thermo® Electronic

Signaling Controller
Self Balancing Indicator
Indicating Recorder

Modern design—proven components—these are the hallmark of the new Thermo Electronic Instruments. And the proof of the pudding, in this case, is in the applicability.

No matter what your process measuring requirements, these instruments will prove unsurpassed for versatility, dependability, long-lived accuracy, sensitivity and speed of response. They will measure any variable translated to DC potential, current or resistance. The instruments have been specially designed for front-set adjustment, ease of operation and maintenance, quick, in-the-field, interchangeability of components and ranges, (from 1 to 100 millivolts). Accuracy is ±0.25% of full scale—sensitivity is ±0.125%. The exclusive new high-gain amplifier, which couples extreme sensitivity with exceptional stability, is utilized in each instrument.



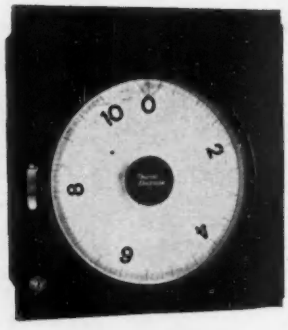
Size

Signaling Controller
Off-on, Potentiometer or Bridge Type

Takes just 56 square inches of panel space. Rugged, compact Signaling Controller automatically, continuously controls any process through DC signaling transducers. Corrective action is almost simultaneous with even a 1 microvolt signal change. Bright red-green lights show process condition. Provides built-in fail-safe action—fully automatic reference junction compensation.

Matched accessories for these instruments

Thermocouples
Thermowells
Extension wire
Connectors
Panels
Switches



Readability

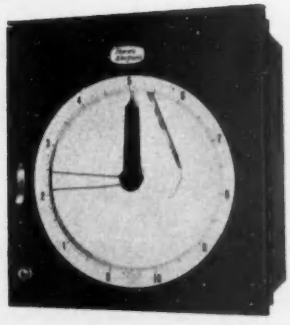
Self Balancing Indicator
Potentiometer or Bridge Type

Rapidly, automatically indicates condition at any one of several hundred sensing elements connected through multi-point switches. Large 34″ scale is easily seen from a distance. Built-in fail-safe action—optional 2 or 3 position controls—up to 6 alarm contacts available.

Versatility

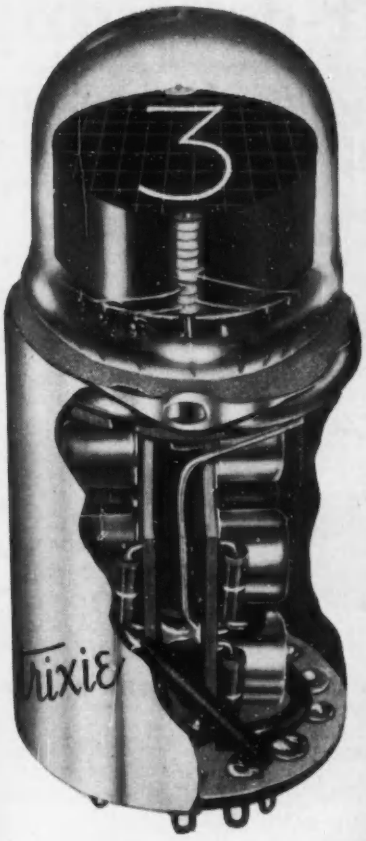
Indicating Recorder
Potentiometer or Bridge Type

Versatility personified, the Indicating Recorder will automatically indicate and record any variable converted to a DC voltage or resistance change. Fine-line recording pen rarely needs refilling. Large 34″ dial is clearly visible from a distance. Full scale pointer and pen travel takes just 5 seconds. Provides built-in fail-safe action—optional 2 or 3 position controls, and up to 6 alarm contacts.

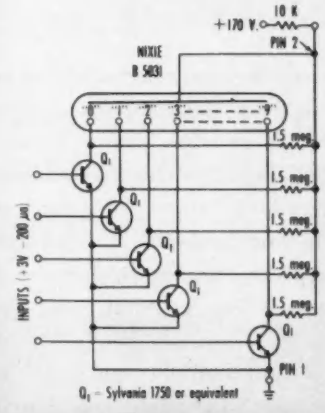


Write today for Bulletin 11

Thermo Electric CO., INC. SADDLE BROOK, NEW JERSEY
In Canada: THERMO ELECTRIC (Canada) LTD., Brampton, Ontario



"TRIXIE" READOUT



Trixie

NEW low-cost TRANSISTORIZED READOUT

Burroughs Corporation

Do you need a small switch with a high current-carrying capacity?...*Acro offers a 10 Amp Miniature and Sub-Miniature Switch.*

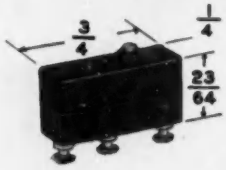
When space, or lack of it, is a stumbling block in your product, Acro miniature and sub-miniature switches can provide a quick solution to your problem.

For Acro miniature and sub-miniature switches carry loads from 3 to 10 amps!

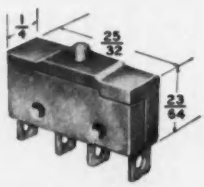
With Acro Miniature and Sub-miniature switches you get big switch performance, long mechanical life (many millions of actuations on most types), and excellent environment characteristics—resistance to extreme temperature and vibration.

Acro miniature switches are also easily ganged for muti-pole application, and are available with very light operating force.

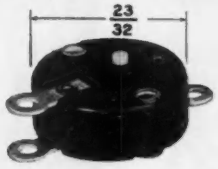
Acro Offers the Biggest Line of Little Switches



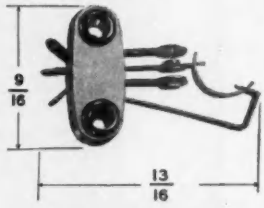
MODEL Z
(Sub-miniature)
High current-carrying capacity, long mechanical life. Designed for AC or DC applications. Available with roller leaf, or straight leaf, overtravel, and manual pushbutton, and toggle actuator. RATINGS: 5 Amp. 120/240 VAC; 30 VDC



MODEL SM
(Sub-miniature)
Up to four times the capacity of other switches, all packed in an assembly that's less than one inch long! Approved by UL for 10 amps, 125-250 volts AC, and 10 amps, 28 volts DC. Double circuit terminals are standard on both normally open and normally closed contacts.

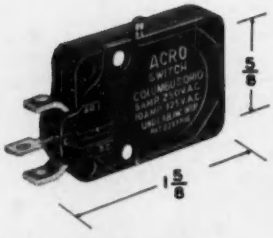


MODEL QD 1000
(Sub-miniature)
Low-cost precision switch, smaller than a dime. 10 amp capacity, works on a very light operating force. Available with disconnect terminals, panel mount, overtravel plunger also provided.

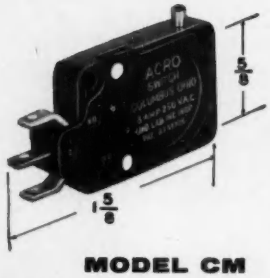


MODEL M-OM
(Sub-miniature)
Here's a real sub-miniature switch — extremely small in size, with an unusual configuration that makes it a real space-saver. Carries a 3 amp load at 125 VAC. Can also be ganged for multi-pole circuitry.

Acro's Miniature Switches



MODEL M
A giant in capacity — a Tom-thumb in appearance. Carries full 10 amps, mechanical and electrical life measured in millions of actuations. Easily ganged for multi-pole circuitry, wide variety of external actuators available.



MODEL CM
Can be actuated by extremely light operating pressures, as low as 20 gms. Can be ganged for multi-pole requirements. Ideal for coin-operated devices or timers. Unlimited variety of actuators available. Rated at 3 amp, 125 VAC.

● No matter what your switching problem — from the miniature and sub-miniature switches shown here — to rugged giants that carry he-man loads — Acro is the source for a quick solution to your problem. Take advantage of Acro's free engineering service. Just write — telling us what you want a switch to do, where it has to fit — and how — and we'll get right to work on it for you. No obligation, of course.

OFFICES IN PRINCIPAL CITIES

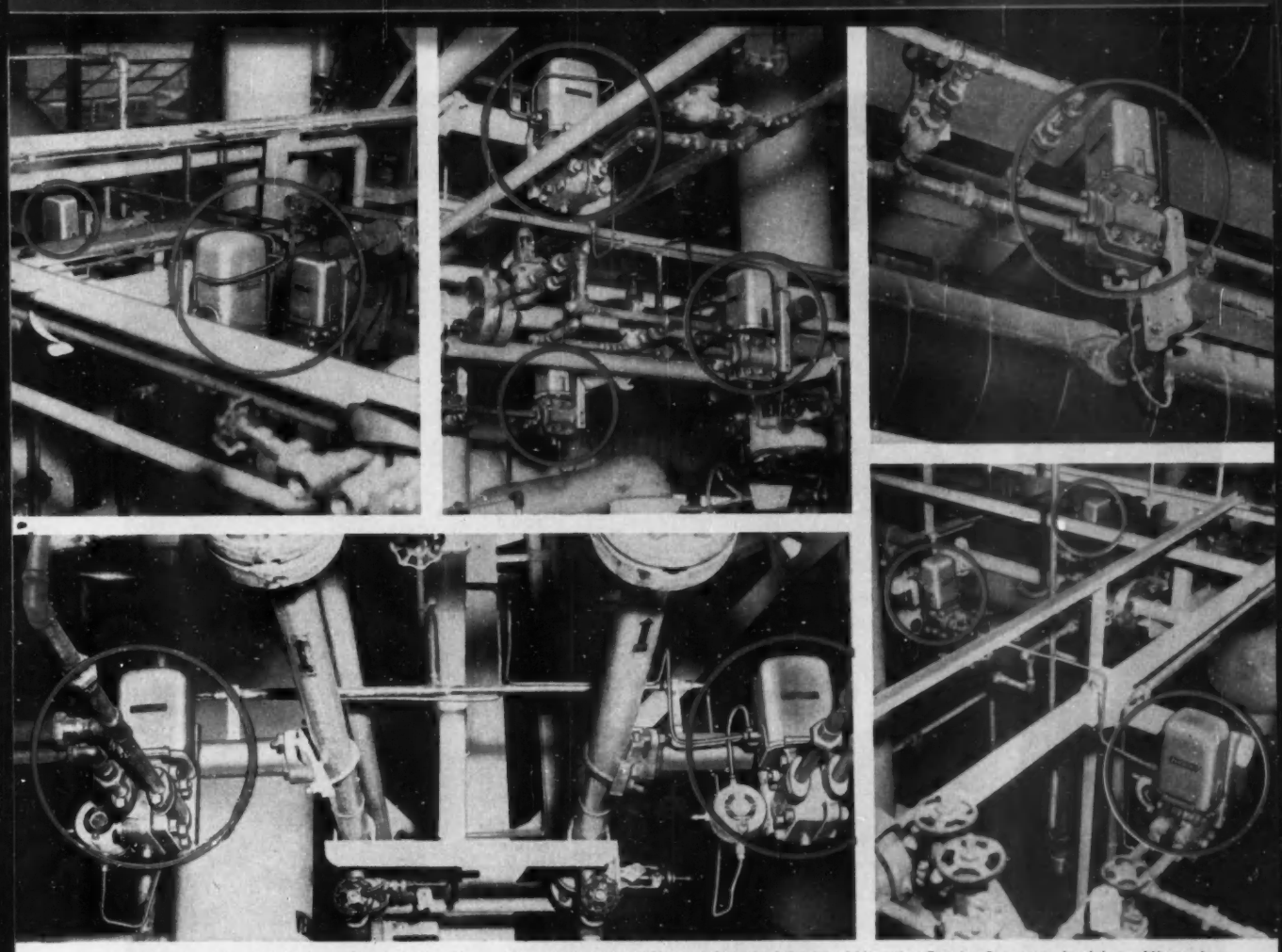
Manufacturers of a complete line of load-tested precision snap-switches and relays

RELAYS ACRO SWITCHES

"OUR 20th YEAR"

ACRO DIVISION Robertshaw

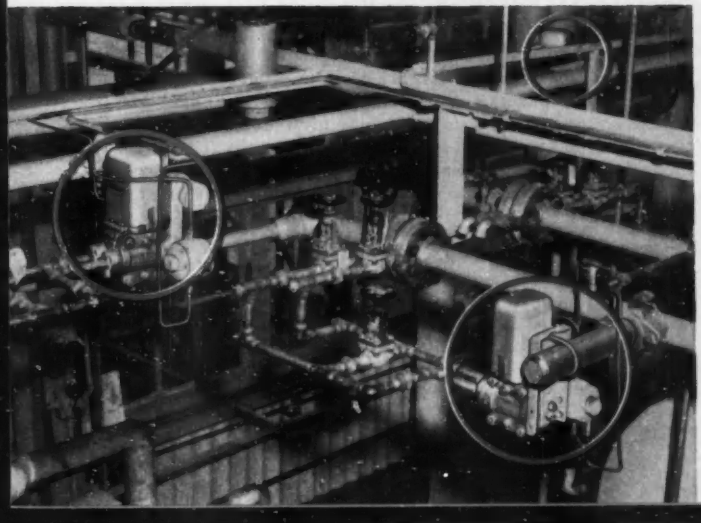
COLUMBUS 16, OHIO



A few of the more than 100 Foxboro d/p Cell Flow Transmitters installed at Missouri Chemical Works of Hercules Powder Company, Louisiana, Missouri.

Hercules' Missouri Chemical Works reports:

"Foxboro d/p Cells* always accurate . . . never need re-calibration"



At Hercules Powder Company's 540-acre Missouri Chemical Works, there are over 100 Foxboro d/p Cell Transmitters in operation today — providing high-speed flow measurement and transmission throughout the ammonia, formaldehyde, methanol and pentaerythritol plants.

"Reliability is the big thing," according to Hercules instrument engineer J. J. VanSchaik. "We can install a Foxboro d/p Cell and forget it. Once it's calibrated, we know it'll stay that way. We never even stock spare parts."

Hercules especially likes the Foxboro d/p Cell for flow control. "Gives us closer control," says instrument engineer H. McCombie. "Eliminates one possible source of inaccuracy and maintenance trouble in the control loop."

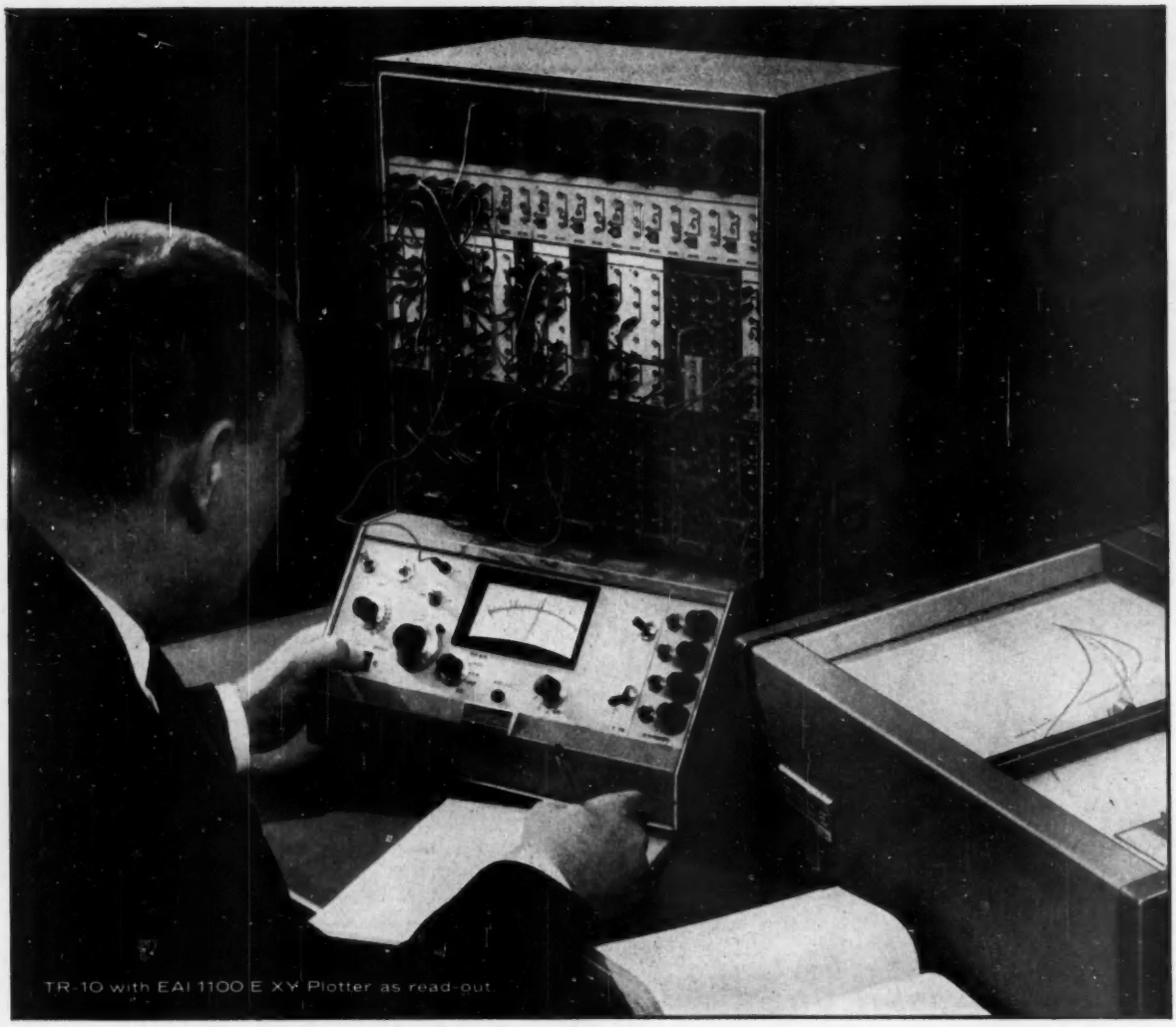
Let Hercules' experience be your experience — with Foxboro d/p Cell Transmitters as the basis for your control system. Write for full details in Bulletin 13-11A. **The Foxboro Company, 852 Neponset Avenue, Foxboro, Massachusetts.**

*Reg. U. S. Pat. Off.

FOXBORO
REG. U.S. PAT. OFF.

FIRST IN FLOW

CIRCLE 55 ON READER SERVICE CARD



THE *FIRST* ALL TRANSISTORIZED ANALOG COMPUTER

—basic model less than $4000

PACE® TR-10 Eliminates Drudgery—Gives New Insight Into Engineering Problems

This compact unit, 15" x 16" by 24" high, is powered by 115 volts AC and can provide day-in day-out instant solution of your most vexing engineering problems. Even if you have never seen a computer before, you can learn to operate the TR-10 as easily as you learned to use a slide rule.

Simply turn a dial to feed in design parameters, and the computer provides an instant by instant, dynamic picture of the effect of each change. You can study the inter-related effects of heat, pressure, flow, vibration, torque or any variable, and visually compare one with the other. Engineering data comes alive – insight into how new designs will work is obtained easier, faster.

Because of its minimum size and low price, the TR-10 can become your own personal analog computer. You gain first-hand experience with the power of analog techniques, and convert more of your time to *creative engineering*. New ideas that were too costly to try before are now practical. You can design virtually to perfection and have a permanent, visual record of performance before building pilot models or prototypes. As a result, "cut and try" expense is reduced.

The same quality workmanship and design that has made Electronic Associates the world's leading producer of precision general purpose analog computers will be found in this new unit. Accuracy to ±.1 per cent. Modular construction allows you to select varying quantities of the following computing functions: summation, integration, multiplication or division, function generation, parameter adjustment, logical comparison.

For complete engineering data, write for Bulletin CC-822A.

EAI ELECTRONIC ASSOCIATES, INC.
Long Branch, New Jersey

How The Biggest User Sees ADP

The U.S. government is by far the world's biggest customer for electronic computers used in business data processing. Because of the huge sums being spent for rentals and purchases of such equipment, Congress has been taking a look at how the government is using automatic data processing (ADP) equipment. Hearings of the Subcommittee on Census and Government Statistics of the Committee on Post Office and Civil Service in the House of Representatives have turned up some data that should be of value to any potential user of computers for business data processing.

Beginning costs

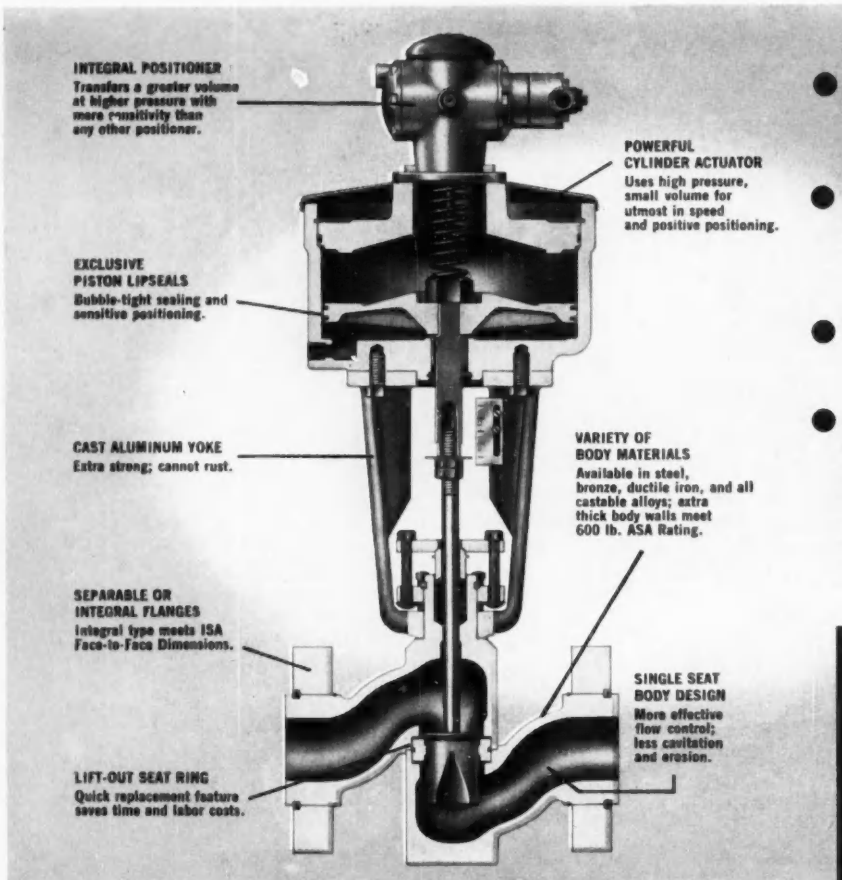
One interesting tabulation reports major preinstallation costs at a number of government large scale data processing installations. Key costs are for a feasibility study, programming the computer, and installing the hardware. The summary of some early installations:

Installation	Machine	Feasibility study costs	Programming costs	Installation costs	Total
DEPARTMENT OF DEFENSE					
Department of the Army:					
AGO, Statistical and Accounting Branch	IBM 705	$35,200	$100,000	$125,000	$260,200
Engineer Maintenance Command	IBM 705	52,800	126,300	334,600	513,700
Ordnance Tank-Auto Command	RCA BIZMAC	107,600	128,800	465,900	702,300
Signal Supply Agency	IBM 705	42,500	90,000	175,400	307,900
Army average		$59,500	$111,300	$275,200	$446,000
Department of the Navy:					
Aviation Supply Office	IBM 702	30,000	106,300	64,600	200,900
Ships Parts Control Center	IBM 705	8,500	81,000	96,000	185,500
Navy average		$19,300	$93,700	$80,300	$193,200
Department of the Air Force:					
Headquarters, USAF, Director of Statistical Services	IBM 705	63,000	97,800	67,900	228,700
Hdqtrs., Air Materiel Command	UNIVAC I	65,200	39,400	100,000	204,600
Air Weather Service, MATS	IBM 705	8,700	60,400	68,500	137,600
Dayton Air Force Depot	UNIVAC I	18,800	131,700	107,400	257,900
Oklahoma City AMA	IBM 702	27,300	12,000	197,800	237,300
Oklahoma City AMA	IBM 705	40,700	46,600	199,000	286,300
Sacramento AMA	UNIVAC I	22,800	105,700	131,600	260,100
San Antonio AMA	IBM 705	47,700	225,400	173,100	446,200
Topeka Air Force Depot	IBM 705	70,000	152,700	131,200	353,900
Air Force average		$40,500	$96,900	$130,700	$268,000
Department of Defense average		$42,700	$100,300	$162,500	$305,500
CIVIL DEPARTMENTS					
Social Security Administration	IBM 705	24,000	89,000	256,700	369,700
Overall average		$41,600	$99,600	$168,400	$309,600

Find the people

Probably the biggest problem, past and future, for data processing users is personnel and training. In 1958 the government had 3,742 people (including both military and civilian personnel) engaged in automatic data processing work in six primary occupations (see table below). Their annual salaries totaled $27 million.

	No. of employees
Digital computer administrator	301
Digital computer programmer	1,773
Digital computer systems operator	621
Peripheral equipment operator	349
Electronic technician	83
Digital computer management analyst	615
	3,742



- **Guaranteed tight shutoff at any pressure or temperature**
- **Simplified construction means less maintenance and fewer replacement parts**
- **Quick delivery in all sizes 3/4" thru 6"**
- **Available in straight-thru, three-way and angle design; also with hand-wheel actuators, manual override, radiation fins and other optional features**

Partial List of Conoflow LB Valve Users:

ALUMINUM CO. OF AMERICA
AMERICAN CAN CO.
ARMOUR & CO.
ARMSTRONG CORK CO.
ATLAS POWDER CO.
BETHLEHEM STEEL CO.
CROSSETT PAPER MILLS, INC.
CROWN-ZELLERBACH CORP.
DOW CHEMICAL CO.
GENERAL FOODS CORP.
HAMMERMILL PAPER CO.
HERCULES POWDER CO.
JONES & LAUGHLIN STEEL CO.
KIMBERLY-CLARK CORP.
OLIN MATHIESON CHEM. CORP.
MERCK SHARP & DOHME
PABST BREWING CO.
REYNOLDS ALUMINUM CO.
JOS. SCHLITZ BREWING CO.
SCOTT PAPER CO.
SEAGRAM DISTILLERS CO.
E. R. SQUIBB & SONS
UNION CARBIDE CORP.
U. S. RUBBER CO.
U. S. STEEL CORP.
WEYERHAEUSER TIMBER CO.

USERS FROM COAST TO COAST SPECIFY

"CONOFLOW LB VALVES

for Automatic Control that's Headache-Proof"

When company after company switches to Conoflow LB control valves—and constantly reorder—there must be a reason. Leading manufacturers use Conoflow LB valves because they want headache-proof control—and they get it. Specify Conoflow LB valves for performance, economy and dependability—*complete* satisfaction. For additional information telephone your Conoflow representative (located in principal cities); or write to Conoflow Corporation, 2100 Arch Street, Philadelphia 3, Pa. for Bulletin LB-3.

CC902

CONOFLOW CORPORATION
FOREMOST IN FINAL CONTROL ELEMENTS

SUBSIDIARY WALWORTH

Projected future manpower requirements are staggering. After hearing plans of government agencies for additional computer installations, the subcommittee estimates that the annual salary bill for U.S. employees in ADP in 1963 will be over $80 million. And the number of people employed in ADP by the government will be almost 13,000.

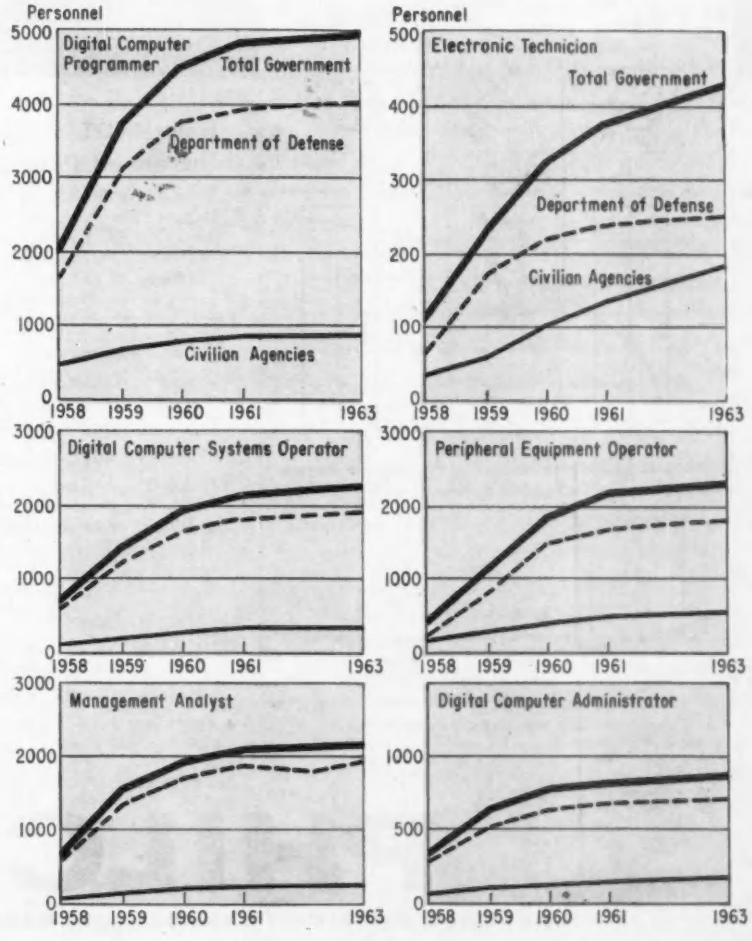
Military growth

Biggest growth will be by the military. The Air Force expects to increase the number of people working in ADP from 1,644 in 1958 to about 4,700 in 1963; the Army plans an increase from 918 in '58 to 3,700 in '63; and the Navy is set to increase its ADP force from 780 to 2,100 over the same period.

But civilian agencies plan healthy increases too. The Veterans Administration, for example, which had less than 50 people in ADP in 1958 expects to have 200 next year. The Post Office Dept. also had less than 50 workers in 1958, may have nearly 100 by the end of this year. In the five years from 1958 to 1963, Dept. of Commerce will boost its ADP staff from under 200 people to over 500, the Treasury Dept. ADP staff will jump from about 125 to 275, and the Dept. of Agriculture will increase its computer workers almost 50 percent.

In numbers the fastest growing field is digital computer programmers. 1,773 were on the payroll in 1958; almost 5,000 will be needed by 1963. Peripheral equipment operators, only 349 strong in 1958, will number 2,200 by 1963. Other growths are projected in the graphs below.

With such expansion planned, government agencies are concerned about where to find qualified ADP people. Four sources, the Congressmen heard, will have to be used: 1) Equipment manufacturers, 2) universities (considered the most important outside resource to meet the training need), 3) special groups like the American Management Association, and 4) the agencies themselves with in-house programs.



Projected Growth of Government Employees in Automatic Data Processing

(1958 figures are authorized rather than actual numbers.)

Control

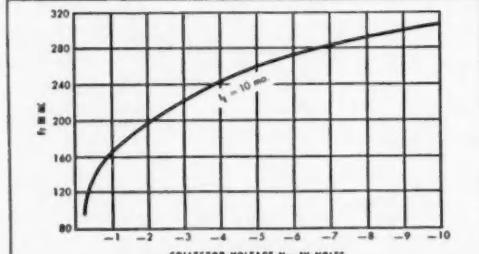
PHILCO ANNOUNCES

NEW ULTRA HIGH-SPEED SWITCHING TRANSISTOR

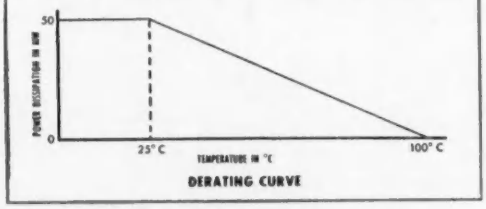
WITH CADMIUM ELECTRODES

...IN TO-9 PACKAGE

SIMPLE 20MC BINARY STAGE



TYPICAL GAIN-BANDWIDTH PRODUCT, f_T VS. COLLECTOR VOLTAGE



DERATING CURVE

New MADT* 2N1500 Provides Increased Power Dissipation

Here is another Philco "break-through" in the design and manufacture of high frequency, ultra high-speed switching transistors! This new Micro Alloy Diffused-base Transistor (MADT*) uses cadmium electrodes in place of indium. The higher thermal conductivity of cadmium insures cooler-running junctions for any given power dissipation and provides an extra margin of safety as added assurance of reliable performance.

The new 2N1500 offers the designer these important advantages:

- 100° C maximum junction temperature
- low collector capacitance
- low saturation voltage
- high Beta and excellent Beta linearity with temperature and current
- low hole storage time (Typical: 7 mμsec)

In electrical characteristics, the 2N1500 is similar to 2N501, which has been thoroughly field-proven in many military and industrial computer applications. It is manufactured on Philco's exclusive fully-automated production lines to the highest standards of uniformity. For complete specifications and applications data, write Dept. **CE-260.**

Max. Ratings		Typical Parameters				
T_{STG} °C	V_{CB} volts	t_r mμsec	t_s mμsec	t_f mμsec	h_{FE}	$V_{CE(SAT)}$ volts
100	−15	12	7	4	35	−0.1

AVAILABLE IN PRODUCTION QUANTITIES... and in quantities 1-99 from your Philco Industrial Semiconductor Distributor.

*MADT . . . TRADEMARK PHILCO CORPORATION for Micro Alloy Diffused-base Transistor.

PHILCO®

LANSDALE DIVISION / LANSDALE, PENNSYLVANIA

TRANSISTOR CENTER U.S.A.

CIRCLE 60 ON READER SERVICE CARD

Control
ENGINEERING

FEBRUARY 1960

From Standard Practice to Unique Design

The spectrum of practice by control engineers is wide. At one extreme is the recruit from other engineering work, a man who is suddenly required to set aside much of his experience and master the principles and practices of control. He must draw on the fund of experience accumulated by engineers who have practiced in the control field for many years, who have found out what will work in run-of-the-mill applications and what will not. His first task is learning accepted practices. "Installing Pneumatic Transmission Systems", pages 137-139 of the January 1960 issue is a set of such practices. While prepared by the Subcommittee on Instruments of the American Petroleum Institute's Committee on Refinery Equipment, it offers excellent guidance to the beginning control technician and engineer in all plants in which pneumatic process control systems are used. We have published it because it is an authoritative statement of good practice and because there is no other means of broad distribution. (See page 139 of the January issue for information on how to obtain an API manual that will contain this and other guides for the installation of instruments.) In the March issue we will publish an API guide to the installation of rotameters. Subsequent issues will include control equipment specification sheets perfected over the years by major process plant contractors.

At the other extreme is the advanced systems engineer, for whom there are few guides to accepted practice. His problem is creating unique systems by adapting what is available and often by designing entirely new subsystems. "Computer Rescues the Voting Process", page 65 of this issue, describes an information control system that is far ahead of standard practice. Its uniqueness required considerable adaptation of the latest techniques and equipment. For instance, its logic operations and memory core planes are adapted from computers and operate at speeds that are nominal for modern computers. But when translated to paper-handling, the speeds far exceed current standards, the system tallying twenty giant-sized ballots a second—a paper-handling speed nine times that of the latest punched-card sorter. Its designers also adapted numerical control techniques to the reading of ballots so that the ballots would not have to be carefully aligned in the tallying machine.

Whatever the industry, control problems are met by approaches that span the range—from standard practice to the creation of entirely new systems. We will continue to publish articles that teach the necessary knowledge.

W. E. Vannah

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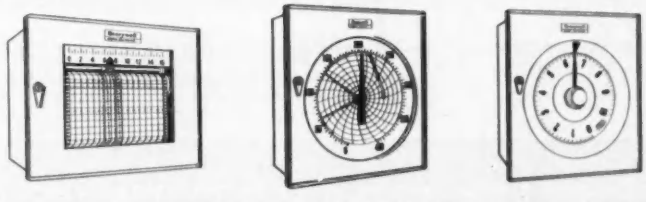

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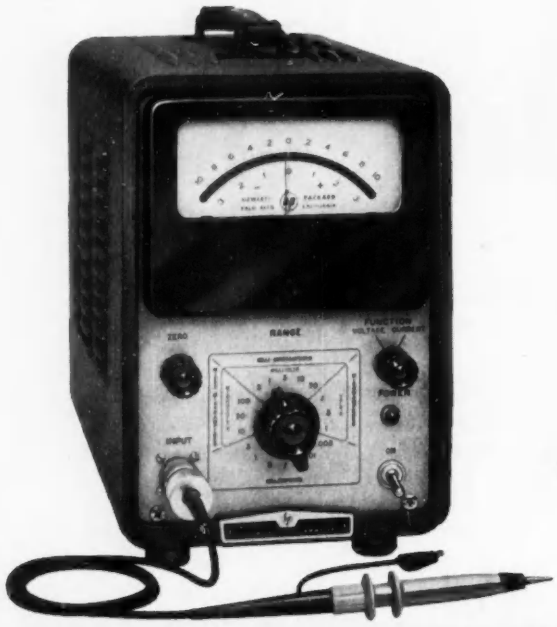

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FIG. 1. Los Angeles' ballot glut. Registrar of Voters Benjamin Hite stands before about 5 percent of the ballots cast in a typical election. Each envelope holds one precinct's votes. Visible are envelopes for only 750 of the more than 11,000 precincts in the county.

Computer Rescues the Voting Process

WILLIAM D. BELL
Tucson, Arizona

Buried in ballots, Los Angeles County's election officials are trying to bring order out of voting chaos with a new, specially developed electronic data handling system. The equipment has to solve two problems: moving the millions of ballots at high speed and counting and tabulating them. Scoring ballots at a rate of 20 per second, the machine can tell in half a minute who has won and who has lost a precinct election.

In sprawling Los Angeles County, tabulating the vote in local elections has become increasingly difficult. There are more than 5,800,000 residents in the county—more people than live in any one of 40 of the states. Political subdivisions within the county include 12 congressional districts and 31 state assembly districts. The result is to make counting the Los Angeles County voting a data handling problem of staggering proportions. But city election officials think they have a solution in a most interesting and sophisticated electronic data processor.

At first glance, the obvious answer to such a problem is voting machines. Benjamin S. Hite, registrar of voters, explains that it has been tried and failed. He says, "We tried it first in 1928 and again in 1949 with trial purchases of machines. After some very unhappy experiences, we disposed of the voting machines in 1952."

The unique structure of Los Angeles County and its strange voting problem preclude voting machines. Part of the problem is cost. Equipping Los Angeles County with mechanical voting machines would cost the taxpayers $30 million. Just storing the 15,000 machines necessary would require a space bigger than three football fields. And transporting them over Los Angeles County's 4,000 square miles for each

election would be difficult and expensive, too.

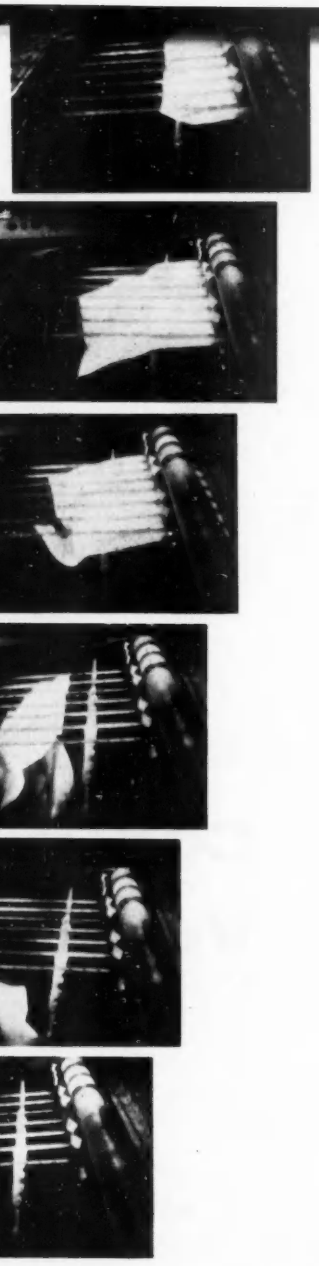
Buried in ballots

But that is not the worst part of the problem. California voting laws make ballot problems difficult. Until recently, cross-filing between different political parties was permitted: a candidate might run for office representing more than one party. The incumbent is always listed first in any voting category, but all other candidates must be rotated in their placement upon the ballot so that all candidates have an equal chance with the voter who simply checks the names at the head of the list. Because there are different congressional and assembly districts within the county, not all voting issues or candidates are common to all of the ballots. The June 1958 primary election required 764 different ballot formats which appeared in six different paper sizes.

In an election each of Los Angeles County's 11,000 precincts is manned by five clerks. Registrar Hite has the awesome chore of recruiting, training, and supervising 55,000 people for a 1-day job. These workers must be at the precinct for the voting day, which is 7:00 am to 7:00 pm. When the polls close, they begin opening the ballots and tallying votes. The law forbids them to stop or leave the precinct until the job is done. All too often, they're still counting at dawn of the following day. And for this, they receive $15.

The direct costs of hiring precinct clerks and renting people's garages for voting space add up to $1 million each major election. When a primary and general election are held in the same year, the taxpayers pay well over $2 million for the privilege of voting. And the county conducts some 200 other elections a year for such things as school boards, water districts, etc.

That, then, describes the voting problem that faced Los Angeles County. In 1956 the County turned to industry for help (CtE, Nov. '56, p. 6).



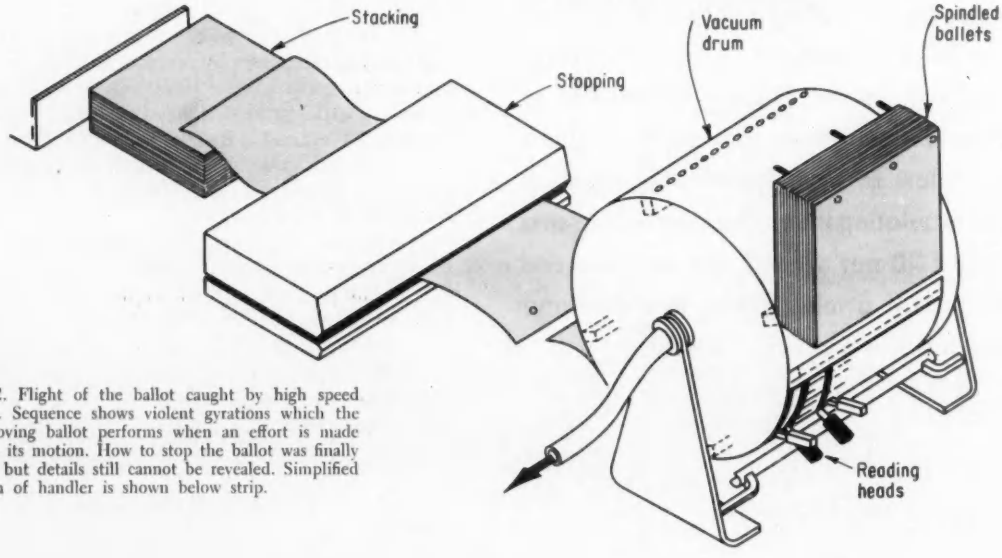


FIG. 2. Flight of the ballot caught by high speed camera. Sequence shows violent gyrations which the fast moving ballot performs when an effort is made to stop its motion. How to stop the ballot was finally solved, but details still cannot be revealed. Simplified diagram of handler is shown below strip.

What the County wanted were "ballot tallying machines". Voters, Los Angeles officials proposed, would continue to mark paper ballots in the conventional fashion, but automatic machines instead of precinct workers would read these paper ballots and accumulate the tallies.

Election officials determined that automatic counters could allow them to put 600 voters into each precinct, instead of the current 300 (a number defined by the precinct workers' tallying capacity and set by the voting traffic), so that the total number of precincts could be cut in half, to 5,500, thus saving $500,000 in each major election. Preliminary estimates indicated that electronic vote tallying equipment would cost about $1 million—a 30-to-1 saving of $29 million over buying voting machines. On this basis the county asked for bids.

Sixteen companies, most of them large, well known corporations, submitted proposals. The equipments proposed ran the gamut of data handling technology. Proposed reading methods used photoelectric sensing, fluorescent inks, and magnetic inks. The counters ranged from mechanical stepping switches to high speed electronic accumulators. The speed with which ballots could be handled ranged from a low of 20 sec per ballot to a high of 20 ballots per sec—a 400-to-1 speed differential. Of the 16 proposals, 14 quoted speeds of 3 ballots per sec or less. The winner, by the Norden Div. of United Aircraft Corp., quoted 20 per sec.

Norden proposed a very sophisticated electronic data processing system. Completely solid-state, it depended heavily on a high speed magnetic core memory for its operations. The critical problem in evaluating Norden's proposal was the relationship of ballot handling speed to equipment cost. Norden's system would require only four ballot tallying pieces of equipment to handle the county's total load. Some of the other proposals required as many as 50 machines. But—and this was the critical question—if the Norden system couldn't handle ballots at high speed, then the electronic portion of the system was too expensive.

Ballot tallying prototype

As a result of the evaluation, the contract for developing a prototype ballot-tallying system was awarded to Norden Div.'s Data Systems Department. Norden in turn subcontracted the mechanical portion of the system to Gyrex Corp. Norden's systems approach is a fascinating application of computer and numerical control technology to a new problem area. The prototype ballot handler is now nearing completion.

The Norden ballot counter will take stacks of ballots as they are received from the precincts, move one ballot at a time through the machine, suck each ballot onto a drum where its fluorescent ink votes can be read by photoelectric cells, correct for skewness of the ballot, perform necessary logic to validate a vote, count the vote, totalize and store the votes for the precinct, and print out each precinct's results.

Paper speed

First, take the matter of paper speed. Twenty ballots a second is a formidable paper handling speed. Veteran printers, who should know more about paper handling than anyone else, said it couldn't be done.

Ballots are big pieces of paper. A typical ballot measures 24 in. in length and as much as 30 in. in width. It is not solid card stock, but instead a big, floppy piece of paper. The voter stamps his crosses on it, folds it up, and then gives it to the precinct worker, who in turn shoves it into a box through a slot. When the election is over, the precinct workers take the ballots out of the box, unfold them, straighten them out, and stack them. These ballots are then put into a machine that will feed them one by one, read the marks accurately, and perform all necessary logic and arithmetic.

To get an idea of the problems involved, compare ballot handling with punched card movement. The latest IBM card sorter will feed 1,000 cards a minute. Since a card is 3¼ in. wide, the paper speed is calculated to be 3,250 in. per min. Moving 20 ballots per sec is 1,200 per min, actually faster than the IBM card sorter. Because the ballot is 24 in. long, the equivalent paper speed is 28,800 in. per min. Thus, the ballot handler is moving flimsy paper nine times as fast as a card sorter!

Registration

There are two aspects to the mechanical problems of handling the ballots. One is picking up the ballot and moving it past the reading heads, and the other is maintaining accurate registration. Norden recognized that with a numerical control system, exact registration of the ballot is *unnecessary*.

As each ballot passes beneath the reading heads, the relative position of two sets of clock marks, printed on each edge of the ballot, is sensed. By digitally measuring the time differential between these two clock marks, the amount of skew in the ballot is accurately determined. The electronic tallying system then introduces a *digital* phasing control for sensing each voting position.

Thus, Norden did not attempt to register the ballot accurately as it passed through the reading station. Instead, the electronic portion of the system is directed to know *when* and *where* to look to interpret the voting squares.

To use the machine, precinct workers stack ballots on a "ballot tray", spindling each ballot on two or more rods through prepunched and slotted holes. The stack of ballots for one precinct is presented to the ballot reader on this spindled tray. As a result, fairly good registration is achieved. A vacuum sucks the ballots from the stack to a vacuum drum. Rigidly plastered to the drum, each ballot passes the reading station, and then is stacked. The time required

to read one precinct's 600 ballots is 30 sec.

Stacking the ballots

In the prototype development, successful operation of the ballot pickup and reading mechanism was quickly achieved. As expected, however, the main difficulties developed in the area of stopping and stacking the ballots. As W. J. Holt, vice-president of Gyrex, said, "As soon as the vacuum lets go of the ballot, it is in free flight, and the aerodynamic problems of a ballot in free flight are insuperable!"

A Fastax camera was used to shoot 2,000-frames-per-sec pictures to find out what was really going on. Figure 2 shows a sequence of this film. Obviously, a ballot moving at this speed is completely out of control. Starting the ballot into motion, accelerating it to reading speed, and actually reading the data turned out to be a relatively easy problem. The really tough task was stopping the ballot. (Gyrex came up with a unique solution, but patent considerations prevent its being described at this time.)

The ballot

A prime requirement for the automatic system was that conventional voting procedure was to be followed. Since there are variations in ballot size from election to election, and even within a precinct in a single election, the mechanical ballot handling system has to be able to adjust itself to variations in ballot size. All ballots will be 24 in. long but they may vary between 4 and 30 in. in width.

From the voter's standpoint, there will be no difference in the new ballot. From a visual standpoint, there are three changes. First and most important, a set of clock marks is printed in both the right- and left-hand margins. These clocks are for the purpose of measuring skew and for accurately locating the positions at which the voter's marks are to be sensed. Second, in the "measures" part of the ballot, the area around the yes-no squares has been blacked out to make certain the voter gets his mark into the proper location. Finally, two or more stacking and alignment holes are accurately punched and slotted in the top edge of the ballot. These are used by precinct workers to spindle and stack the ballots before sending them to be tabulated.

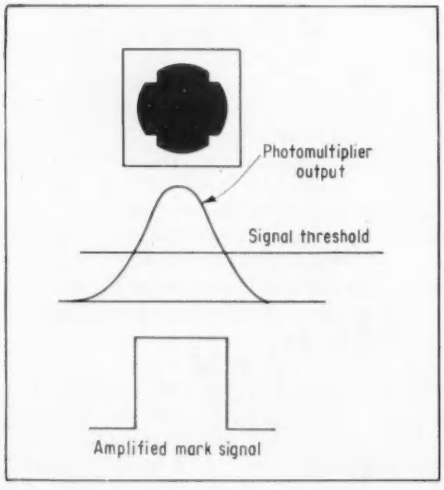
The voter's mark

The voter will continue to mark his choices using a self-inking rubber stamping device. The conventional cross used formerly has been changed to the form shown in Figure 3—a circle with four corners nicked out to give the appearance of a cross. This figure provides minimum signal differentiation as a result of cross orientation. The ink itself will be fluorescent. Thus, as each ballot passes the reading station, it is energized by an ultraviolet source and the voter's marks are sensed by photoelectric eyes sensitive to the spectrum of the fluorescing ink.

In tallying ballots a voter's mark is counted if one-half or more of the mark is inside the voting square. This is not just a rule for the mechanical vote tallying system; rather, it is the legal rule that is followed by precinct workers in manual tallying.

An acceptable voter's mark is determined by accurately sensing at two precise time intervals in each possible voting position. In Figure 3 the photomultiplier output is amplified to produce an essentially square-wave signal. The time-phase relationship of this signal is then tested by a pair of strobe pulses. If coincidence is found between the amplified photomultiplier signal and either one or both of the strobe pulses, then the voter's mark is at least one-half within the square and is counted acceptable.

Obviously, if a ballot passes the reading station at anything other than an accurate 90 deg, then the voting spaces cannot be examined simultaneously. For this reason, the skew correction already described has been incorporated. The time-phase correction applied is a function of the amount of skew in the ballot and the voting column on the ballot. The column is important because read-out is accomplished by a series of heads placed along a line parallel to the drum axis. Skew correction is made by counting the number of high speed processor clock pulses between the sensing of the first right and first left clock tracks. The number is proportionally divided among the several columns (which may be of different widths) and each of the new values trans-



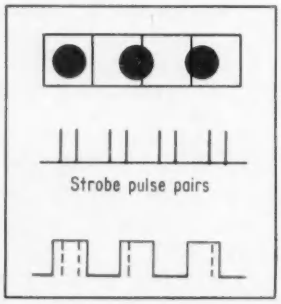


FIG. 3. Voters mark (top) is read by photomultiplier tube whose output is amplified into a square wave. To authenticate the vote, a pair of strobe pulses have to be superimposed on the square wave (at right), proving that at least half the voter's mark is in the measuring square.

lated into appropriate time delay for control of the strobe pulses.

The core memory

The heart of the ballot processor is a high speed, magnetic core memory. This memory is 10 columns wide and 60 columns deep, a total of 600 core positions in each plane. These 600 positions provide more storage space than the number of voting positions on the largest ballot. In the third dimension the memory has 18 core planes. Allocation of the memory to different functions is as follows:

- One plane stores a ballot image. The memory keeps pace with the ballot so that when the last square on the ballot has passed the reading station, an exact copy of the voter's marks is registered in the processor memory.
- One plane stores where offices begin and end to define the allowed number of votes for each. These data are loaded into the memory from a punched paper tape prior to ballot processing for each precinct.
- One plane marks the location of a recall office and controls processing of information for that office —a very special logical case that occasionally occurs. If an issue is the recall of an elected official and at the same time there are candidates listed for filling the recall position, then a voter is allowed to vote for a candidate only if he has voted (either yes or no) on the recall issue itself.
- One plane marks overvotes. From the office demarcation information and the allowed number of votes for that office which are stored in the overvote control plane, the system knows the maximum permissible number of votes in each office or issue. The most common case is voting for only one out of several. There are other possibilities, however; California law permits voting for as many as seven for the County Central Committee.
- Twelve planes store the total votes cast for each candidate or issue within one precinct. Using binary coded decimal, this is sufficient to store the tally for 999 voters, which is more than the maximum number of registered voters in a single precinct.
- One plane is included to act as a replacement unit in case of a failure of a plane and/or to provide for logical expansion of the system.
- The 18th plane is a parity check plane. A parity bit is generated each time information is written into the memory. Whenever data are read from memory, the entire 18 bits corresponding to one ballot position are read in parallel.

Seeing electronic speed

It is obvious that a great many things happen very rapidly during the 50 millisec it takes to read a ballot. The voter's marks are sensed and transferred to the memory. All the logical manipulation necessary to determine whether each vote is acceptable must be completed. Finally, every one of the individual tallies on every candidate and issue on the ballot must be increased if the voter has made the appropriate marks. In terms of the electronic circuitry and computer-type logic, the requirements are nominal. The data processor operates at a basic clock frequency of 300 kc. The memory itself is operated on a cycle of 6⅔ μsec read, wait for processing followed by 6⅔ μsec write. But although engineers are used to thinking and talking in terms of milliseconds and microseconds, it is not often that they have the chance to see what these time increments really mean in terms of human senses and reaction time. When Norden's electronics people first watched the ballot processor operate, they were startled.

Harold Sarkissian, manager of the Norden Systems Dept., watched 20 ballots read. When the machine was turned off, he asked, "Why did you stop?" What had happened, of course, is that the 20 ballots had been fed and stacked so quickly that Sarkissian had not seen them.

The reaction of Jerry Mendelson, head of Systems Engineering, and Jerry Nishball, project engineer, was that it just didn't seem possible to perform the required operations in the passage time of one ballot. They hurried back to check their calculations.

My own reaction upon first seeing the ballot handler in operation was to think of its effect on people who are not acclimated to this millisecond-microsecond business. I have a mental picture, for instance, of a politician who is running in the election that is being counted, watching the machine operate. The ballot handler is started, the ballots go screaming through in a blinding flash of white, the machine is stopped, and then someone turns to the politician and says, "You lost!"

Dual ballot handlers

The maximum number of voters in any precinct will be 600. Assuming a 70 percent turn-out, and an operating speed of 20 ballots per sec, the machine will need only 21 sec, to read and tally all the ballots for a typical precinct. Obviously, a major portion of the operating time will be devoted to placing the ballots in the ballot handler and removing them from the stacker. Recognizing this problem, the ballot processor has been designed with one set of redundant electronics and two sets of ballot handling equipment. While the operators are setting up one ballot handler, ballots can be in motion in the associated ballot handler. Idle time for the electronic portion of the system is thus cut down, reducing the total amount of hardware.

As totals are accumulated for a precinct, or a party within a precinct, they are read out of the core memory and punched into IBM cards. The readout is programmed by perforated paper tape for each precinct. Even though there are many ballot formats, all cards are punched with standardized fields for all candidates and issues. The cards are used to prepare final tabulations and official reports.

Cyanamid's Approach to Computer Control

First cure process imbalances and shortcomings, then choose best computing-control system.

HERBERT GROHSKOPF
American Cyanamid Co.

American Cyanamid Co. puts the performance and capacity of a chemical process at the focus of efforts to obtain improved economic returns and treats control systems as valuable tools which will pay for themselves handsomely. In line with this approach, Cyanamid recently initiated a basic engineering study of a major chemical process with the following objectives: to evaluate the maximum steady-state capacity of all process stages, to define optimum process operation as it now exists, to determine the most economically justified plan for balancing process capacities and for process expansion, and to evaluate economic advantages of computer controls for the balanced and expanded plant.

Chemical processes are usually designed without the help of reaction rate equations, without information about the sequencing and phasing of reaction steps, and with relatively limited study of heat and material balances. Given this design basis, the process improvement team must approach capacity expansion and process control as follows.

Steady-state study

The basic steady-state study, an analytical procedure, includes writing the differential equations describing the operation of each major reaction and separation unit and then solving the equations for steady-state conditions. The resulting sets of simultaneous materials-balance and energy-balance equations relate outlet compositions to inlet temperatures, flow rates, and compositions. The equation parameters call for detailed knowledge of the materials processed, the plant heat and mass transfer coefficients, the physical dimensions of equipment, and the reaction kinetics coefficients. Because of their complexity, the sets of equations are best solved by an off-line digital computer. The unit's inlet conditions, carefully selected to cover the total operable range, yield corresponding outlet conditions.

Plant tests verify computed results. A team of chemists, control engineers, and experimental statisticians plan the experimental design to assure reproducible results and accurate estimation of parameters. Test results will usually indicate the need for adjustment and reestimation of reaction kinetic coefficients and adaptation and refinement of the basic, steady-state process model.

The verified process model is then used to compute and evaluate true plant capacity at various throughput levels. The level at which process performance deteriorates defines each unit's upper capacity limit. The design features limiting unit capacity are varied on the computer, permitting evaluation of the effect of increased heat transfer, recycle rate, and compressor and purification capacity on overall plant capacity. Completion of this study phase clearly defines the economics of capacity expansion. By balancing process flow, heat, and mass transfer capacities, some aspects of the process control problem may be solved.

At times, such as when the cost of a basic study of a complex process is prohibitive or when such studies are technically impossible, regression models will end up the only recourse in making process analyses. Using least-squares data fitting techniques, the set of best performance curves or surfaces is calculated from existing process data. Better still, planned experiments on the plant provide the necessary data for working up such a model. In either case, performance extrapolation into operating regions not achievable in existing equipment is shaky at best. Control applications based and justified on regression models must be subjected to stringent plant verification tests, and the payout of such applications must be clear and undoubted.

After the economics of capacity balance and expansion have been evaluated, the economics of control systems, including computer control, are evaluated for the existing and the possible expanded capacity. If the economics look favorable for the anticipated steady throughput—under optimum conditions—a study of process dynamics is begun.

Process dynamics study

The steady-state process models are extended to describe operation of each unit as a function of velocity and space or of time. Plant operation is again studied, this time by analog computer. Plant tests verify and improve predictions of the dynamic model. The response of the uncontrolled process unit model is investigated for various types of operating disturbances, giving an estimate of the operating improvement to be expected from a given control system. An attempt is made to determine the "optimum" plant controller which serves as a reference against which to evaluate the effectiveness of alternate control systems.

The next phase consists of analog computer tests of several alternate control systems which may give satisfactory performance. A compromise in both cost and efficiency is effected between the optimum scheme and a control system which does assure adequate process performance. Finally an economic balance is worked out between control systems for each process unit and for integrated central process control. Where integrated central control looks feasible, technically and economically, expected process performance is evaluated by off-line digital computing.

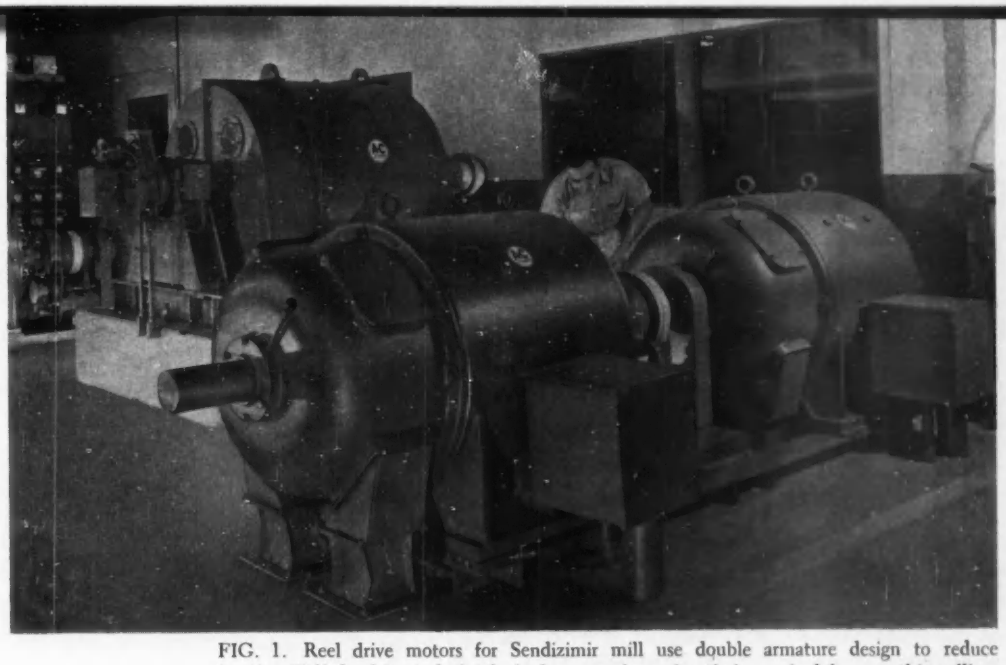


FIG. 1. Reel drive motors for Sendizimir mill use double armature design to reduce inertia. Half the drive is declutched when even lower inertia is required for very thin rolling.

Graph Simplifies Reel Drive Calculations

HANS L. STEINMETZ
Allis-Chalmers Mfg. Co.

This new analysis of accelerating and decelerating characteristics of strip windup reels includes all the pertinent system parameters. It gives you an easy-to-use graph that quickly yields accelerating current for any coil diameter. The graph also shows the way to minimum power requirements.

When a reel drive is designed to maintain constant tension on a strip during winding or unwinding, careful attention must be paid to the effects of the changing reel diameter on torque requirements. This problem is generally solved for dc reel drives by simple but time consuming calculations of instantaneous armature currents demanded for acceleration or deceleration of changing reel inertias to the new rotational velocities necessary for a constant tension strip. A new analysis has been made of this problem that takes into account all the parameters which affect the accelerating and decelerating characteristics.

The reel drive analysis yields two useful results:

- a nondimensional graphic relationship between accelerating torque and reel diameter that permits easy optimization of system parameters in the design stage for the least change in armature current over the range of coil buildup and therefore minimum power requirements.
- a set of three expressions characteristic of reel drives and a simple graphical solution for armature current demands over the range of coil buildup.

Derivation of reel drive characteristics

The following analysis is made for the case of accelerating a winding or motoring reel, which requires increasing drive torque. (The same is true

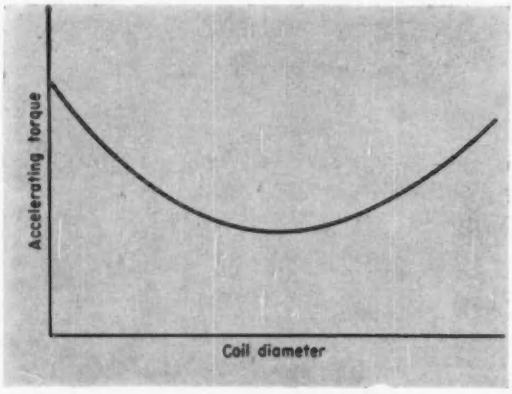


FIG. 2. Typical torque requirements for accelerating coil of strip material vs coil diameter.

of decelerating an unwinding or generating reel.) The derivation holds in general since only the sign of the torque has to be changed if decelerating a winding reel or accelerating an unwinding reel.

The total moment of inertia of a reel system is the sum of the moments of inertia of all the rotating parts including the coil. Referred to the motor shaft,

$$\Sigma WK^2 = WK^2_{motor} + WK^2_{gear} + \frac{1}{(G.R.)^2} WK^2_{mandrel} + \frac{1}{(G.R.)^2} WK^2_{coil} \quad (1)$$

in which

$$G.R. = \text{gear ratio} = \frac{N_{drive}}{N_{coil}}, \text{ and } N = \text{rpm}$$

Equation 1 is the first of the three characteristic expressions that describe the accelerating and decelerating properties of reel drives.

The torque required to accelerate the total moment of inertia in Equation 1 is:

$$T = \frac{\Sigma WK^2}{g} 2\pi \frac{dN_{drive}}{dt} \quad (2)$$

in which g is the acceleration due to gravity. This can be rewritten in terms of the acceleration of the coil as

$$T = \frac{\Sigma WK^2}{g} 2\pi(G.R.) \frac{dN_{coil}}{dt} \quad (3)$$

since the coil rpm times the gear ratio equals the drive rpm. But the coil rpm is a function of strip velocity v and coil diameter D, i.e.,

$$N_{coil} = \frac{v}{\pi D} \quad (4)$$

Substituting the derivative of Equation 4 into Equation 3 expresses the acceleration torque as a function of the total moment of inertia, the gear ratio, the coil diameter, and the strip acceleration.

$$T = \frac{\Sigma WK^2}{g} \frac{2(G.R.)}{D} \frac{dv}{dt} \quad (5)$$

The total moment of inertia (Equation 1) however, also includes the moment of inertia of the coil, which is a function of the coil diameter:

$$WK^2_{coil} = \frac{\gamma w \pi}{32} (D^4 - D_i^4) \quad (6)$$

in which γ = specific gravity of coil
w = width of coil
D_i = coil inside diameter

Substituting Equation 6 into Equation 1 and then rewriting Equation 5 yields the correct expression for accelerating torque as a function of coil diameter:

$$T = \left[WK^2_{fixed} + \frac{\gamma w \pi}{32(G.R.)^2} (D^4 - D_i^4) \right] \frac{2(G.R.)}{gD} \frac{dv}{dt} \quad (7)$$

where $WK^2_{fixed} = WK^2_{motor} + WK^2_{gear} + \frac{1}{(G.R.)^2} WK^2_{mandrel}$

The plot of Equation 7 shown as Figure 2 is therefore a typical accelerating torque vs coil diameter curve for any reel drive system. Note that there is a minimum torque requirement at some particular coil diameter, which can be calculated by taking the derivative of Equation 7 with respect to the coil diameter and equating it to zero:

$$\frac{dT}{dD} = -\frac{2(G.R.)}{gD^2} \frac{dv}{dt} \Sigma WK^2 + \frac{\gamma w \pi}{4(G.R.)g} \frac{dv}{dt} D^2 \quad (8)$$

which then can be solved to get the diameter for minimum torque:

$$D_{T(min)} = \left(\frac{WK^2_{fixed}(G.R.)^2}{\gamma w \pi / 32} - D_i^4 \right)^{1/4} \quad (9)$$

For dc reel drives the accelerating torque (Equation 7) is easily restated to describe the accelerating armature current as a function of coil diameter. This restatement requires two assumptions that are generally valid for dc drives:

- motor field excitation is constant during speed changes.
- the emf of the drive motor at any given diameter is proportional to strip speed v. (The method is also applicable for field control with constant armature current). The two basic equations for the constant-field dc drive are thus

$$T = \frac{K}{2\pi} \Phi I \quad (10)$$

and

$$E = K \Phi N_{drive} \quad (11)$$

in which

Φ = flux
I = armature current
K = a design constant
E = emf

Solving Equation 11 for the flux Φ and substituting in Equation 10, which can then be solved for I yields

$$I = \frac{2\pi T N_{drive}}{E} \quad (12)$$

But

$$N_{drive} = \frac{v(G.R.)}{\pi D} \quad (13)$$

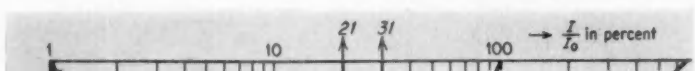
so

$$I = \frac{2Tv(G.R.)}{ED} \quad (14)$$

from which Equation 7 can be rewritten as

$$I = \left[WK^2_{fixed} + \frac{\gamma w \pi}{32(G.R.)^2} (D^4 - D_i^4) \right] \frac{4v(G.R.)^2}{EgD^2} \frac{dv}{dt} \quad (15)$$

Since drive emf and strip velocity are assumed pro-



portional to each other, their ratio is a constant most easily calculated from their rated values (which should thus be used in Equation 15).

Taking the derivative of Equation 15 with respect to coil diameter and equating it to zero produces the coil diameter at which the drive armature current is minimum

$$D_{I(min)} = \left(\frac{WK^2_{fixed}(G.R.)^2}{\gamma w \pi / 32} - D_c^4 \right)^{1/4} \quad (16)$$

which is the second expression characteristic of dc reel drives. The relationship between the diameter for minimum current (Equation 16) and diameter for minimum torque (Equation 9) is interesting:

$$\frac{D_{I(min)}}{D_{T(min)}} = 3^{1/4} \quad (17)$$

The third characteristic expression results from a comparison of the required accelerating armature current with the rated current of the drive. Such a comparison can be made if the expression for accelerating current in Equation 15 is reduced to a simpler function of coil diameter. From Equation 16,

$$WK^2_{fixed} = \frac{\gamma w \pi}{32(G.R.)^2} (D^4_{I(min)} + D_c^4) \quad (18)$$

which, when substituted into Equation 15 yields

$$I = \frac{\gamma w \pi v}{8EgD^2} \frac{dv}{dt} (D^4_{I(min)} + D^4) \quad (19)$$

Solving Equation 19 for minimum armature current by using the value of $D_{I(min)}$ for coil diameter D yields

$$I_{min} = \frac{\gamma w \pi v}{4Eg} D^2_{I(min)} \frac{dv}{dt} \quad (20)$$

Substituting Equation 20 into Equation 19 and dividing by the rated armature current then gives the ratio of the armature current needed for acceleration to the rated armature current of the drive.

$$\frac{I}{I_o} = 0.5 \frac{I_{min}}{I_o} \left[\frac{D^2}{D^2_{I(min)}} \left(\frac{D^4_{I(min)}}{D^4} + 1 \right) \right] \quad (21)$$

The quantity

$$0.5 \frac{I_{min}}{I_o} \quad (22)$$

is the third expression characteristic of reel drives.

A graphical solution

A composite graph has been developed (Figure 3) which permits easy graphical solution of Equation 21. Only the 45-deg line representing $0.5\ I_{min}/I_o$ needs to be moved to represent any reel drive system with a constant field dc motor. The relationship of the parabolic curve representing the function of diameter to the various abscissa scales must not be changed. (The scale for I/I_o is placed at the top of the graph only to simplify its use and could just as well be at the bottom with the others.)

To use this graph it is first necessary to plot the $0.5\ I_{min}/I_o$ line for the particular system. This constant can be found by solving Equations 16 and 20 and dividing by the rated armature current. The abscissa scales are so arranged that this value should be multiplied by 100 to express it as a percentage and plotted on the horizontal line representing an ordinate of unity. Extending a line through this point upwards to the right at 45 deg then produces the necessary curve for multiplication by this constant on this log-log plot. Entering the graph vertically with the value of any given diameter (normalized by dividing by the diameter for minimum current calculated from Equation 16) to the diameter curve and then moving to the right or left to intersect the constant line yields the accelerating cur-

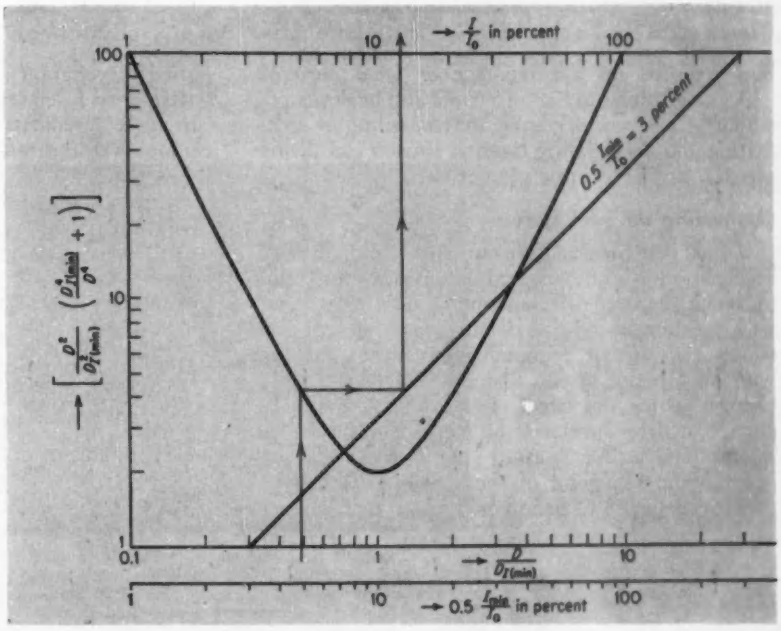


FIG. 3.
Normalized graph developed for solution of Equation 21. To use, graph is entered at normalized diameter $D/D_{I(min)}$, vertically to parabola, then to left or right as required to intersect $0.5\ I_{min}/I_o$ line, and the value of I/I_o read from scale at top. Solution illustrated for $D/D_{I(min)} = 0.5$ and $0.5\ I_{(min)}/I_o = 3$ percent shows armature current required for acceleration equals 13 percent of rated current.

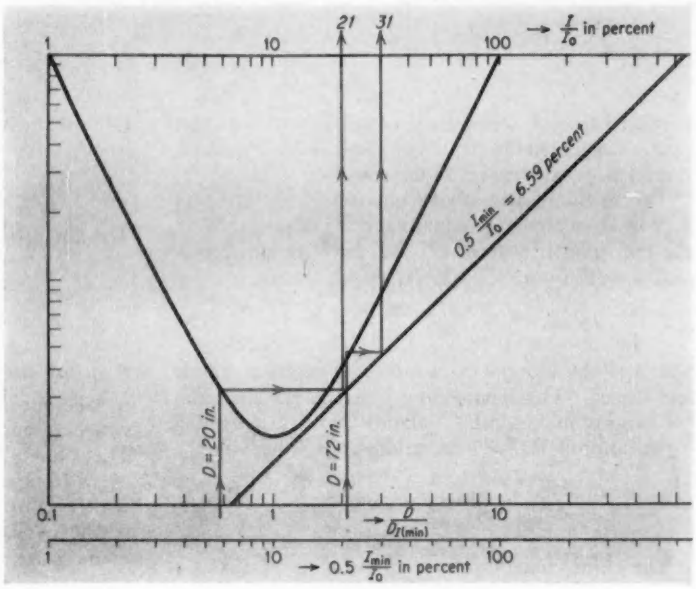


FIG. 4. Use of graph of Figure 3 for solution of illustrative example. Only change from Figure 3 is new position of 0.5 I_{min}/I_o line.

SOLVING A TYPICAL REEL DRIVE SYSTEM

Only three characteristic quantities have to be evaluated to solve any constant field dc reel drive system using the graph presented. These quantities are 1) the fixed part of the rotating inertia, WK^2_{fixed}, 2) the diameter for minimum current, $D_{I(min)}$, and 3) the value of 0.5 I_{min}/I_o.

The strip coiler following a cold strip steel mill, for example, might have the following parameter values:

WK^2_{drive} = 5,500 lb-ft², referred to drive shaft
WK^2_{gear} = 1,150 lb-ft²
$WK^2_{mandrel}$ = 2,100 lb-ft², referred to mandrel

$$G.R. = \frac{N_{drive}}{N_{coil}} = \frac{1.22}{1}$$

I_o = 640 amp D_i = 20 in.
E = 750 volts v = 3,000 ft/min
ρ = 7.08 $\frac{dv}{dt}$ = 150 ft/min/sec
w = 48 in.

Therefore,

$$WK^2_{fixed} = 5{,}500 + 1{,}150 + \frac{1}{(1.22)^2} \times 2{,}100$$

$$= 8{,}395 \text{ lb-ft}^2$$

From Equation 16,

$$D_{I(min)} = \left(40{,}750 \times \frac{8{,}395 \times (1.22)^2}{7.08 \times 48} - (20)^4\right)^{1/4} = 34 \text{ in.}$$

And from Equation 20,

$$0.5\,\frac{I_{min}}{I_o} = \left(\frac{10^{-5}}{56}\right)\left[\frac{7.08 \times 48 \times 3{,}000 \times (34)^2 \times 150}{750 \times 640}\right]$$

$$= 0.0659 = 6.59 \text{ percent}$$

(The number 40,750 in the solution of Equation 16 includes π, g, and other numerics to make the dimensions cancel, as does the term $(10^{-5}/56)$ in the solution of Equation 20.)

For an empty mandrel, or $D = D_i$ = 20 in.,

$$\frac{D}{D_{I(min)}} = \frac{20}{34} = 0.588$$

The graph in Figure 4 shows that, for acceler. tion of this reel system and an empty reel, an accelerating current I = 21 percent of I_o = 134.5 amps is needed.

For a maximum coil diameter of D = 72 in.,

$$\frac{D}{D_{I(min)}} = \frac{72}{34} = 2.12$$

Figure 4 shows that acceleration of the reel system and a full reel requires an accelerating current of

$$\frac{I}{I_o} = 31 \text{ percent} = 195 \text{ amps}$$

Accelerating current can be determined in this way over the complete range of coil build-up.

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rent required (as a percentage of rated current).

A graph similar to Figure 3 could also be developed which would permit graphic determination of accelerating and decelerating times at various coil diameters for any given armature current.

Optimizing the reel system

Notice that the armature current requirements for acceleration can be separated into two sections: one in which the current requirements tend to decrease with an increase of coil diameter and a second in which the current requirements tend to increase with an increase of coil diameter. This is due to changes in the net effect of the decreasing rate of change of drive rpm and the increasing coil inertia as coil diameter increases.

From the viewpoint of the control system for a dc drive designed to maintain constant strip tension during acceleration and deceleration, an optimized system would demand the least change in armature current requirements during acceleration and deceleration over the range of coil build-up. Figure 3 shows that such an optimum is obtained when the armature current requirements at the two extreme coil diameters are equal. Thus a system with prescribed material, width, and inside and outside coil diameters can be optimized by proper choice of drive gear ratio or inertia, as in Equation 16.

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INSTRUMENT UNCERTAINTIES—PART II

What About Scale Factor and Resolution?

Continuing his exposition on the origins, definitions, and specification of instrument errors, author Entin concentrates on such factors as linearity, resolution, and threshold.

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Instrument uncertainties, or errors, fall into three major categories: uncertainties of zero, uncertainties of scale factor, and uncertainties of instantaneous slope. Part I of this two-part series ("Is The Zero Output Really Zero?", CtE, Dec. '59) defined an instrument's ideal linear characteristic, described how the three types of uncertainties progressively reduced allowable deviation from nominal, and then examined uncertainties of zero. This article concentrates on scale factor and instantaneous slope.

Uncertainties of scale factor

The actual output curve of a typical instrument is shown by the heavy line in Figure 1. The light straight line is the nominal static characteristic. It has two significant features: it passes through zero and has the correct slope $\Delta E_o/\Delta W$. The actual characteristic, then, contains two classes of errors—zero and scale error. Zero error (at zero input) has been discussed in Part I. Scale error enters when the input is not zero.

The nominal scale factor is the slope of the nominal static characteristic. The actual scale factor, considered at any instantaneous point P_1 on the generalized output curve of Figure 1, can be defined in several ways, as follows:

1. Tangent-scale factor is slope of true tangent to the output curve. This is difficult to test.

2. Secant-scale factor is slope of line connecting P_1 and some adjacent point P_2, where the increment $P_2 - P_1$ is defined as some small fraction of full scale. This is alternatively known as local slope and is sometimes specified by stating that it must not differ from average slope (to be defined below) by more than a stated amount.

3. Apparent-scale factor is slope of line connecting 0 and P_1. This is misleading if zero uncertainty $0—0'$ is appreciable.

4. Average-scale factor is slope of best straight line passing through the zero-input point 0′. In all instruments wherein the nonlinearities are reasonably evenly distributed about null, this line will also be simply the best straight line.

The average-scale-factor definition is the recommended one because it permits separation of the zero from the scale factor uncertainty. Also, the best-straight-line-through-actual-zero (point 0′) reference will be recommended for the linearity definition.

The user's specification of scale factor should include the nominal plus upper and lower limits. The resulting total uncertainty will then appear as shown in Figure 2 in which the band of constant width represents the permissible errors due to zero uncertainty. The diverging lines represent the extremes of allowable scale error adding simultaneously to the zero error, defining a total bandwidth within which the actual instrument output must fall. Zero error is generally expressed as a fraction of full scale input, scale factor error, on the other hand, as a fraction of the instantaneous input. So the total uncertainty specification usually appears as

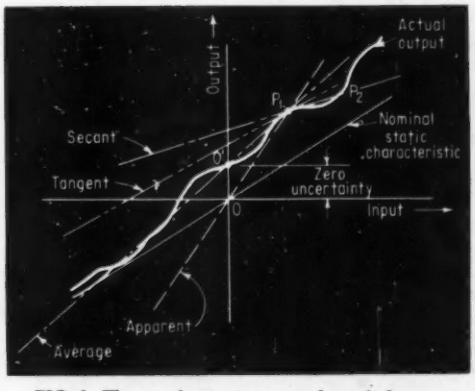


FIG. 1. The actual output curve and nominal static characteristic of a typical instrument. The differences between actual and nominal comprise two types of uncertainties, zero error and scale error.

FIVE WAYS TO SPECIFY LINEARITY

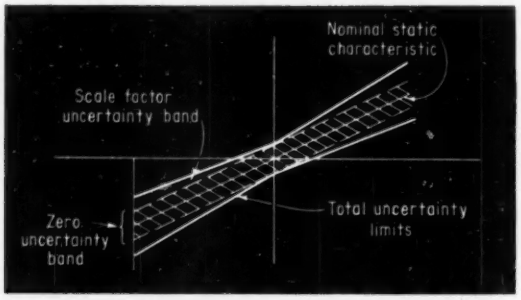


FIG. 2. Graph of an instrument's total uncertainty, which may also be expressed by an equation as described in the text.

Maximum uncertainty =
± X percent full scale ± Y percent reading
(zero error) (scale error)

To be definitive, such an overall specification must clearly state the range and combination of environmental and power supply conditions for which it is intended to apply. Its inclusion in an instrument specification helps in immediately establishing the instrument's quality level.

The important elements that contribute to scale factor error are nonlinearity; manufacturing tolerances; and power supply, load, and temperature variations.

Linearity—is the conformance of an instrument's output curve to a reference straight line under standard environmental and power supply conditions. Linearity disregards absolute output magnitudes and zero drift. It indicates the basic linearity of the essential elements that make up the instrument. Nonlinearities arise from predictable factors like geometrical output droop, as in the case of electromagnetic decoupling decreasing the effective fraction of motor output torque with increasing angular displacement between armature and field windings. They are also caused by nonpredictables like component nonlinearity, as in the case of the progressive stiffening of certain types of springs as a function of deflection.

Such nonlinear effects produce output deviations from the reference line. The next problem is that of choosing a suitable reference. A variety of references lines can be used as the basis for linearity determination, and therefore the exact definition which the user intends to apply should be clearly stated. The table lists five linearity definitions.

Of the definitions listed in the table, *actual zero-based linearity* is recommended since it includes only that type of error of immediate interest in the linearity specification. Zero and slope (calibration) errors should be covered elsewhere in the spec.

One way to call out the linearity requirement is on the basis of constant fractional accuracy, *CFA*:

Independent linearity = ± X percent of input reading

But there is a practical drawback to such a specification. Good inspection procedure dictates that the combined guaranteed accuracy of test equipment should be ten times better than the reading X. Therefore:

Test equipment linearity = 0.1 times *X* percent input reading

At say 1 percent of full scale input, the test equipment linearity must then be 0.1×0.01, or 0.001 FS. Thus, although constant fractional accuracy gives a good representation of actual instrument linearity, it imposes some impractical and unrealistic test requirements.

A more useful linearity specification reaches this compromise:

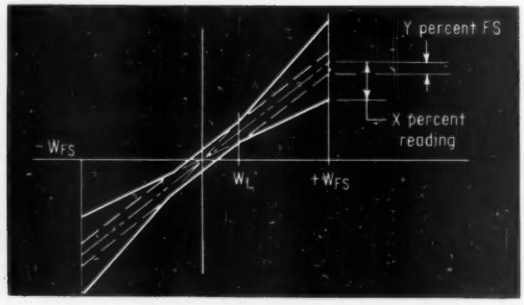
Independent linearity = ± X percent input or ± Y percent full scale, whichever is greater

The resulting permissible output band is shown in Figure 3. Here, W_1, the input at which X percent reading equals Y percent full scale, must be selected by the user such that the resulting implied test equipment accuracy is within practical bounds. Such a specification recognizes that practically speaking—while one could never conclusively prove an instrument met the CFA specification over the whole operating range anyhow—it is reasonable to assume that the absolute magnitude of the linearity errors approaches zero in the lower input region. In other words, an instrument that meets the specification shown in Figure 3 would also be likely to meet the equivalent *CFA* specification.

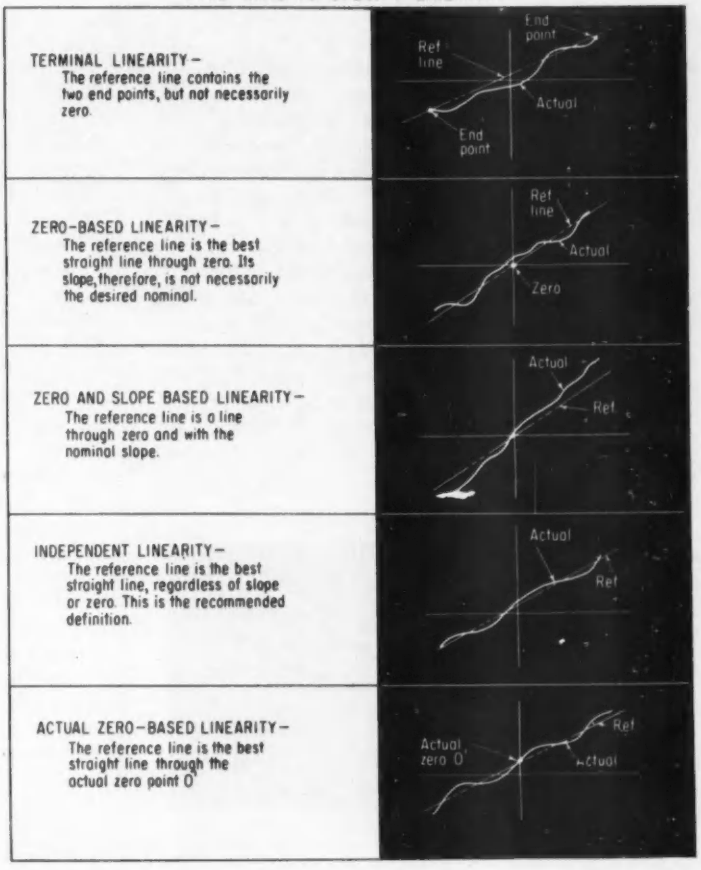
Manufacturing tolerances—Included in the total uncertainty specification, Figure 2, are variations in scale factor which result from cumulative manufacturing tolerances. It is not economical to attempt, during manufacture and initial assembly, to control each variable to better than a few percent of its nominal. Therefore, even under standard conditions and with nominal excitation, the instrument's static scale factor might differ from the nominal by a substantial amount. As an example, the unadjusted scale factor of a rate gyro may vary as much as plus or minus 15 percent from nominal.

Excitation variations—also cause scale factor errors. Changes from nominal of power supply voltage,

FIG. 3. Typical permissible output band associated with the specification of linearity.



FIVE WAYS TO SPECIFY LINEARITY



current, and frequency vary an instrument's output with a given input. Sometimes the scale factor error is linear with respect to a power supply variation. More frequently the error is nonlinear.

The user must specify the maximum effects that excitation variations may have on scale factor. Such a specification would include not only what might be termed the results of imperfect instruments but also the effect of excitation imperfections on perfect instruments. Assuming the user's requirements are reasonable, the maker can often correct for excitation variations by incorporating compensation networks in the instrument.

Temperature variations – are prime sources of scale factor errors. Almost all instrument components are electrically and/or mechanically sensitive to temperature changes. For instance, the modulus of elasticity of spring materials decreases with increasing temperature, so that an instrument signal dependent on spring deflection will exhibit a scale factor error unless compensated for in some manner. The relation between modulus of elasticity and temperature is well known and can be accurately established for any material. (Low-hysteresis spring materials are available which have an elastic modulus that remains virtually constant over a wide temperature range.)

Another, and frequently more important, effect of temperature variation is a change in the instrument's electrical impedance. Resistance of copper windings is particularly temperature dependent, varying about 40 percent for a 100 deg C temperature change. To minimize temperature effects in many ac instruments, it is highly desirable that the reactive component of the impedance dominate the resistive component.

In that portion of an instrument specification concerned with scale factor uncertainties, the user should:

1. Specify the maximum permissible scale factor uncertainty, computed by taking the statistical sum (root-sum-square) of the individually contributed sources.

2. Specify those individual uncertainties which should be separately controlled. Linearity is typical of such an uncertainty.

3. List all sources whose effects must be considered in the total scale factor uncertainty.

Uncertainty of instantaneous slope

An instrument's uncertainty of instantaneous slope (of the static output characteristic) is related to the fact that an output increment does not always accompany an input increment. As a result, the input-output curve, Figure 4, appears to have steps. The instantaneous slope at the risers of any of these steps is theoretically infinite. Consider the important features associated with a typical step:

1. Input increment—This is the change in input (ΔW) required to increase E_s from that at P_1 to that at P_2.

2. Output increment—This is the change in output level (ΔE_s) which occurs almost instantaneously when the input increment equals ΔW. Note that ΔW may be gradually applied, but even so ΔE_s is a sudden occurrence.

The input increment ΔW is often called the *dead zone*. Its permissible magnitude must be specified by the user. Dead zone is directly related to such factors as hysteresis, threshold, and resolution. Unfortunately these latter terms are too often used improperly in specifications prepared by users and makers alike. A rigorous discussion follows.

When a user sets out to specify a dead zone, he generally defines it as that input increment ΔW required to produce an output increment ΔE_s of some specified magnitude. The ΔE_s magnitude is not always clear, however. Such loose terms as any "meaningful" or "discernible" change, although often used, are really unsatisfactory. ΔE_s is better specified by one of the following methods:

1. Absolute value—ΔW is that input increment required to produce an output increment ΔE_s equal to X percent of full scale. Note that ΔW is some percentage, say Y percent, of full scale. In absolutely perfect instruments, X would equal Y at all times. In general, X is selected to equal or be less than Y. Therefore the ΔE_s which is required to eventually occur by the time ΔW reaches its limit

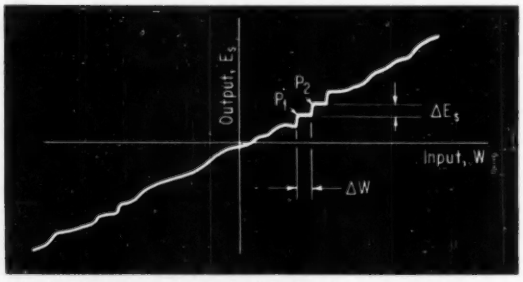


FIG. 4. Many instruments exhibit a stepwise relationship between input and output increments, giving rise to an uncertainty of instantaneous slope.

may be less than or exactly proportional to but never greater than ΔW. A further requirement implicit in this type of test is that the instrumentation monitoring the input and output signals must be capable of discerning percentage changes an order of magnitude smaller than X or Y.

2. Signal-to-noise ratio—ΔW is that input increment required to produce an output increment ΔE_s equal to n times the residual noise level. Noise here includes harmonics and quadrature voltages. Such a definition applies particularly where the output is not filtered or phase detected. In these cases the signal-to-noise ratio is critical, since an instrument which senses only rms depends on the signal exceeding the noise by some amount before the instrument can discern the difference between noise rms and signal plus noise rms.

Either of the above methods of specifying ΔE_s puts the user and maker on common ground. Specification of the permissible uncertainty of instantaneous slope is effectively accomplished by specifying *resolution* and *threshold*.

Resolution—is that minimum input increment ΔW which, anywhere in the instrument's operating range, is required to produce the arbitrarily specified output increment ΔE_s.

Threshold—is that minimum input increment ΔW which, starting from the zero input condition only, is required to produce the arbitrarily specified output increment ΔE_s.

Threshold, then, is essentially resolution at null. Threshold defines the absolute magnitude of the smallest measurable *input*, while resolution defines the magnitude of the smallest measurable *input change*.

Hysteresis—is an uncertainty of zero (Reference) rather than an instantaneous slope uncertainty, and that distinction will be retained here. This distinction is justified: even though an instrument with high hysteresis is usually thought of as having poor resolution, some closer thought shows that this is not necessarily so. Resolution is not particularly affected by, for instance, a torsion spring, but hysteresis is quite dependent on it.

When preparing instrument specifications it is recommended that, unless otherwise specified, resolution and threshold requirements be considered to apply under standard conditions of excitation and environment. Some environmental conditions affecting resolution and threshold measurements are dither, sustained linear acceleration, and ambient temperature.

Dither—is a continuous, random, low level vibration. Most airborne and even some ground-based instruments (such as those mounted on or near rotating machinery) are subject to dither. Dither helps in reducing the effect of static friction within the instrument and thereby improves resolution and threshold. When possible, dither should be called for in the specification.

Linear acceleration—is probably the major environmental factor contributing to high resolution values for such airborne instruments as nonfloating gyros with one or more gimbal bearings. (Ground-based instruments will not be subject to such sustained linear acceleration, but may be to shock forces.) Increased loading of gimbal bearings caused by the acceleration increases the friction level and, therefore, the input (resolution rate) required to overcome the friction. It is extremely difficult to experimentally determine resolution in the presence of a sustained acceleration because of the difficulty of developing accelerations by centrifuges and acceleration sleds, without introducing extraneous motions whose effects mask the resolution test.

Ambient temperature—changes considerably for both airborne and ground-based instruments, and such changes may affect both resolution and threshold values. Fortunately it is a relatively simple matter to determine dead zone over the range of operating ambient temperatures.

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Mechanical Power Amplifier Boosts Torque, Transmits Position

THE GIST: Many of today's machine tools and automatic processes require precise positioning or movement of heavy loads. Often this motion must be generated at a low torque level and then amplified to match the load. This article describes the operation and several applications of an all-mechanical power amplifier for this purpose.

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The principle of the capstan has been known and used for many years, particularly aboard ship. Essentially, it provides power amplification through the control of friction forces. Figure 1 illustrates a modern version of this principle. The motor-driven cylinder or capstan rotates in the direction shown. In A the rope is slack and slips on the cylinder. In B a slight input force is applied. This takes up the slack and immediately increases the friction force acting on the rope until the rope no longer slips but moves with the cylinder. In the example shown, a 20-lb input force suffices to lift a 100-lb load. Actually, the amplification factor depends on the number of turns of rope on the cylinder and the coefficient of friction between the two materials.

In 1927 the Bethlehem Steel Co. recognized the fact that two such capstans working in opposite directions would not only amplify but would also provide position control. This led to the development of a simple closed-loop device in which single bands were expanded within drums. Attempts to improve performance by using materials with high friction coefficients led to inconsistent and unpredictable operation. A Canadian development, using several turns of metallic ribbon, was also limited in amplification because of the instability inherent in the band design. Finally, after careful consideration of band stiffness factors, materials, and lubricants, a multiple-turn design was evolved which provided the necessary stability without sacrificing

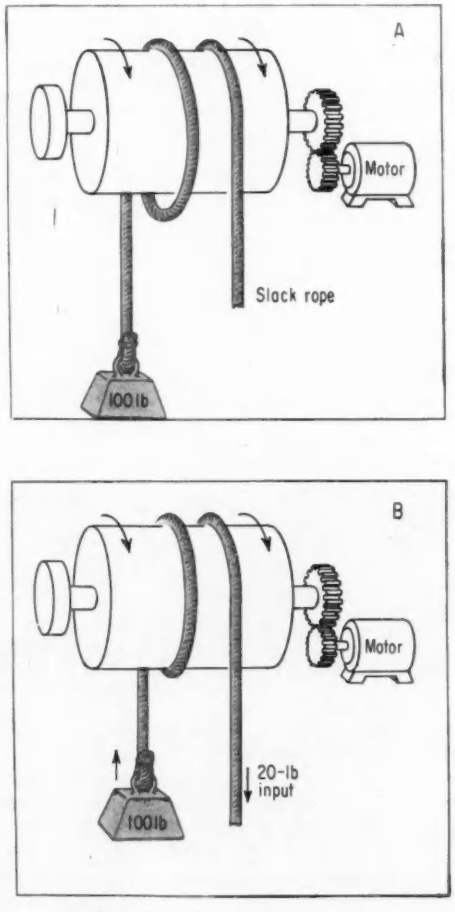


FIG. 1.
Simple illustration of the capstan principle.

SIX WAYS THEY'RE BEING USED

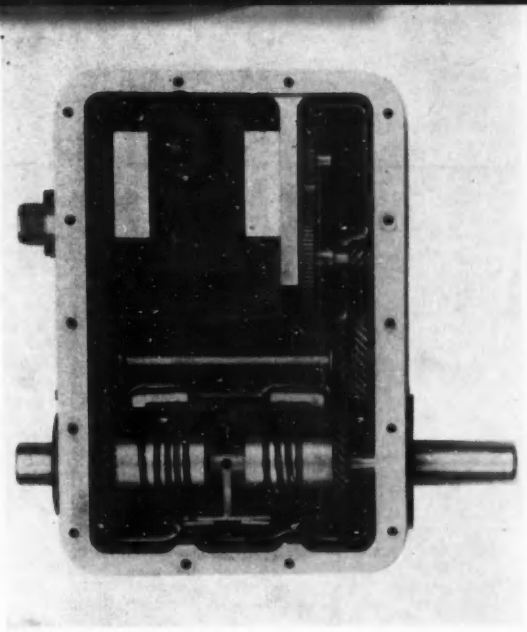
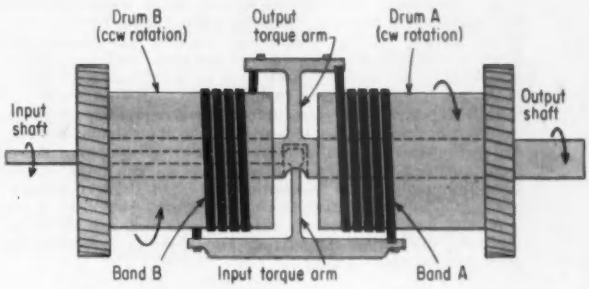


FIG. 2.
A mechanical power amplifier based on counterrotating capstan design.



amplification. The following pages discuss the operation and several current applications of this device.

Operating Principles

Figure 2 shows how the device works. The input ends of both bands are connected to a torque arm on the input shaft. Bands are wound about the counterrotating drums and then connected to a similar torque arm on the output shaft. To illustrate its operation, let the input shaft be rotated a given amount in a clockwise direction. Band *A* will immediately tighten on drum *A* and cause the output shaft to follow the input. At the same time the input shaft tries to loosen band *B*, but this effort is neutralized since the output shaft tries to tighten band *B*. When the input shaft stops, tension in band *A* relaxes and drum *A* no longer transmits torque. If the output shaft tries to coast, band *B* tightens immediately on the counter-rotating drum *B*. This quickly brings the output shaft to a stop. Thus, regardless of the pattern of input motion or speed, the amplified output follows in an exact relationship. Power to do work is supplied by any rotational power source. Drum rotation is independent of input and output shaft rotation.

Servosystem actuators, whether electrical, mechanical, hydraulic, or pneumatic, exhibit two widely different levels of performance with regard to response and accuracy. In one type the power source starts and stops with each input signal, whereas in the other the power source runs continuously and is instantaneously connected to the load by the input signal. For example, a hydraulic servo provides relatively fast response when the pump in the system continuously produces the necessary hydraulic pressure. However, if the input signal must first activate a motor-pump combination to build up pressure, response is relatively slow. The first system would have an inherent rapid response; the latter would offer a lower operating cost but would also have a much longer time constant.

The mechanical power amplifier described above falls into the fast response category. Power from its continuously rotating drums is instantaneously available. For position control applications, pneumatic, hydraulic, and electrical systems, even with continuously running power sources, require transducers of some kind to change signals from one energy form to another. The mechanical power amplifier, on the other hand, permits direct sensing of the controlled motion. When necessary, however, it too can be driven by an electrical input through a servomotor or similar device. These other systems also require external means for feeding back position and rate information. Such feedback is inherent in the mechanical amplifier.

Briefly, the four major advantages of this all-mechanical device may be summarized as follows:

1. Kinetic energy of the power source is continuously available for rapid response.
2. Motion can be duplicated and power amplified without converting energy forms.
3. Position and rate feedback are inherent design characteristics.
4. Zero slip between input and output eliminates the possibility of cumulative error.

One other important advantage worth noting is the ease with which this device can be adapted to perform special functions—jobs for which other types of systems would require the addition of more costly and perhaps less reliable components. The six applications which follow illustrate how these advantages have been put to work in solving widely divergent problems.

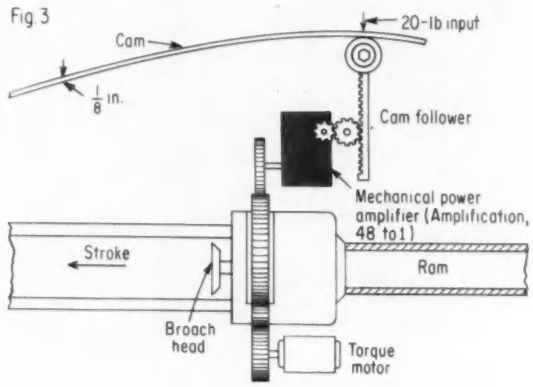
SIX WAYS THEY'RE BEING USED

1. Nonlinear broaching

PROBLEM: In broaching large bore rifles, the twist given to the lands and grooves represent a nonlinear function of barrel length. Development work on such rifles usually requires some experimentation with this function. At present, rotation of the broaching head is performed by a purely mechanical arrangement consisting of a long heavy wedge-type cam and appropriate gearing. For steep twist angles, however, the forces acting on this mechanism become extremely high. Since experimental work requires frequent variation of the cam shape, the cost of machining a variety of such heavy tools has become difficult to justify.

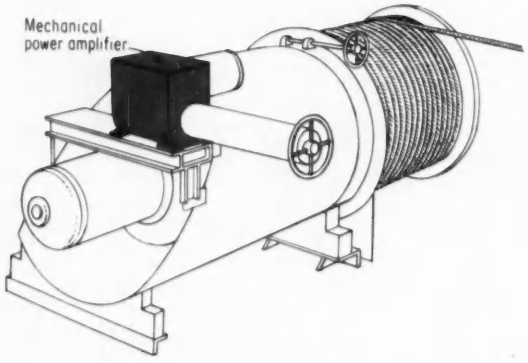
SOLUTION: A suitable mechanical power amplifier, with its inherent position feedback, was added to the existing mechanical arrangement, as shown in Figure 3. The cam and follower, instead of having to drive the broaching head, simply furnish enough torque to position the input shaft of the amplifier. A suitable torque motor eliminates backlash. Cams can now be fabricated at a fraction of the cost of those formerly used thus permitting far more experimentation with various twist angles.

Fig. 3



2. Hydraulic winch control

Fig. 4



PROBLEM: Hydraulic pump-motor systems represent an excellent method of controlling position and motion at high power levels. In the 10- to 150-hp range, for example, the usual approach is to vary the output of a positive displacement pump in a closed-loop hydraulic circuit. In many of the systems that might be used to control this displacement, however, a force feedback proportional to system pressure can lead to serious errors or even oscillations.

For one application, a hydraulic winch control, it was necessary to amplify input torque to a specified value and then transmit all higher values without amplification. The system also had to provide for reflecting output overloads back to the input on a 1 to 1 basis while still amplifying the input torques to the equivalent rated output.

SOLUTION: Figure 4 shows an external view of the complete package. The output shaft of the mechanical power amplifier controls pump displacement, while its input is controlled by hand. In a more recent development, requiring remote manual control, a servomotor replaces this local handwheel. Approximately 10 lb-in. torque drives a 600 lb-in. load. If this system had to transmit 600 lb-in., the equipment would be more expensive and more dangerous.

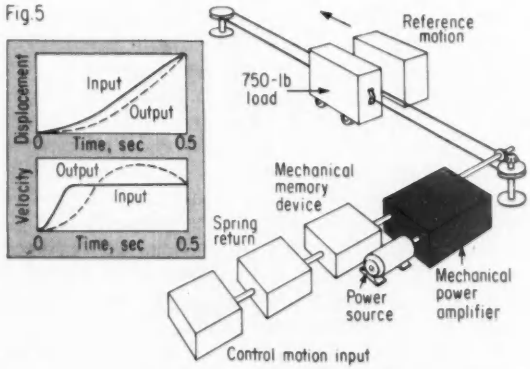
Within the mechanical amplifier, preloaded springs on the band attachments provide exact position transmission at a 60 to 1 amplification and, at the same time, permit any overloads, either on the input or output side, to be reflected through the amplifier at the required 1 to 1 ratio.

3. Load positioning

PROBLEM: A customer required that a 750-lb load be accelerated from standstill in 0.5 sec and brought into speed and position synchronization with a reference linear motion. It was also necessary that the source of control motion be permitted to accelerate more rapidly than the load itself. At the same time, position of this input source had to be preserved. Therefore torque applied to the load could not be limited by means of a slipping device.

SOLUTION: A system using a single mechanical power amplifier provided the solution, Figure 5. Here a mechanical memory device preloaded for either rotation is used to drive the input shaft of the amplifier. This permits the input source to accelerate as rapidly as desired. Total control input travel minus the input travel of the amplifier shaft is temporarily stored. After 0.5 sec the load reaches proper speed, and the memory device transmits position information in exact synchronization with the input. Behavior of the system during the acceleration period is shown by the curves.

Fig. 5



4. Irregular routing

PROBLEM: A manufacturing firm had decided to remotely control table position of a routing machine from information stored on a film strip. The servoloop developed to interpret this information produced only about 1 oz-in. of torque. About 20 lb-ft was required at the table feedscrew.

SOLUTION: Figure 6 shows how a mechanical power amplifier supplied the necessary torque at the remote table location. A position transmitter converts the rotary motion output of the servoloop to a proportional electrical signal and sends it to a differential amplifier at the machine location. A position receiver, geared to the output shaft, provides a signal proportional to table position. The differential amplifier compares these, amplifies the difference, and sends a signal to either counterrotating electromagnetic clutch, which drive the input shaft of the mechanical power amplifier.

In this particular application the system had to respond to approximately 1,000 reversals per min. Small 5-watt clutches provided this response. Had the mechanical power amplifier not been used, the system would have required a 40-watt electronic amplifier and much larger clutches capable of responding to only 20 reversals per min.

Fig.6

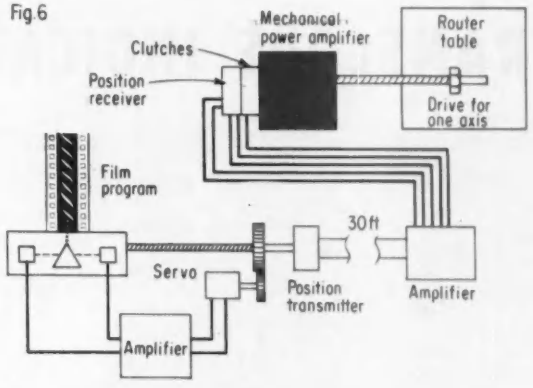
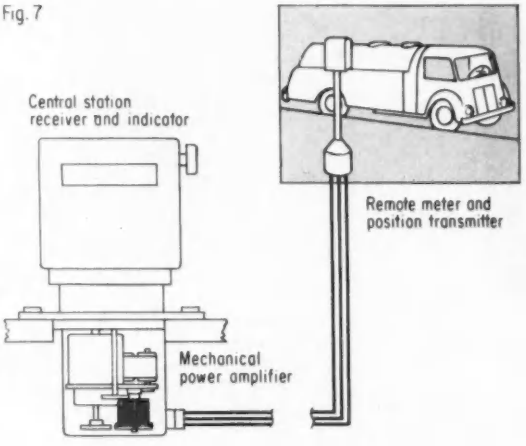


Fig. 7



5. Remote metering & counting

PROBLEM: For a remote liquid metering job, synchro systems had been used to transmit remote meter readings to a central station and repeat this information on local indicating counters. The operation involved a large number of meters and indicators. As new devices were added (ticket printers, for instance), the torque requirement also grew.

Attempts to provide the necessary torque at the indicators by increasing the size of the synchro receivers and transmitters had two serious drawbacks: cost of the telemetering systems increased, and accuracy fell off. Loss of accuracy was caused mainly by the additional torque load on the rotors of the remote meters.

SOLUTION: Use of mechanical power amplifiers in the central station indicators not only supplied the extra output torque but also made it possible to use synchros even smaller than those originally selected to drive the indicators alone.

The synchro transmitters currently used operate at a maximum speed of 600 rpm and produce only about 3 oz-in. of torque. The mechanical power amplifiers furnish up to 100 lb-in. and are designed to fit in the bottom of the registers as shown in Figure 7. Accuracy of the total flow is within 0.25 gallon. Since there is no slip between input and output shafts, error is noncummulative.

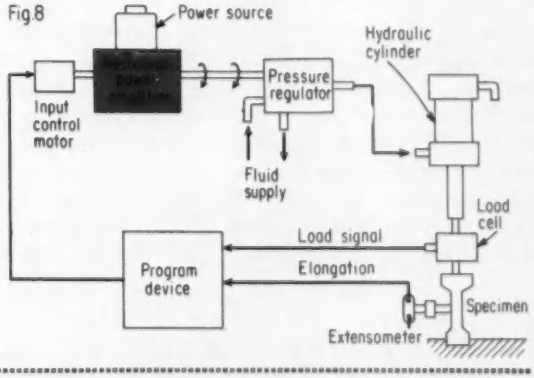
An investigation of the more classical electromagnetic servo and amplifier approach indicated that such a system would cost about three or four times as much and would require additional equipment not readily adapted.

6. Tensile testing machine

PROBLEM: On a hydraulic tensile testing machine, stroke of the power cylinder had to be controlled as a function of two variables: tension in, and extension of, the test specimen. A programming device, designed to provide a control signal proportional to these variables, had an output power level of about 0.001 hp—too low to drive the pressure regulator controlling the flow to the cylinder.

SOLUTION: An analysis of the problem revealed three requirements: output of the programmer had to be amplified about 60 times, position accuracy had to be within 2 deg, and acceleration had to be held at a very low value. A mechanical power amplifier satisfied all three requirements. Figure 8 illustrates the completed system. Its design is based principally on steady-state characteristics.

Fig.8



Taylor ANNOUNCES THE TRANSCOPE* INDICATOR

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- Color-coded target-type pointers against full 10″ scale—for exceptionally easy reading.
- Powerful "Servomatic" powered pointers—assure precisely accurate pointer positioning.
- Front-of-panel control response settings give results at a glance.
- Same standardized components as in the 90J Recorder—minimum parts inventory necessary.
- In a control station, continuous indication of set, process and valve pressure.

Optional features include: indication of a second variable on a separate dial; Cascade switch for pneumatic set control; electric or pneumatic process alarms.

For full details, call your Taylor Field Engineer, or write for **Catalog 98347.** Taylor Instrument Companies, Rochester 1, New York, or Toronto, Ontario.

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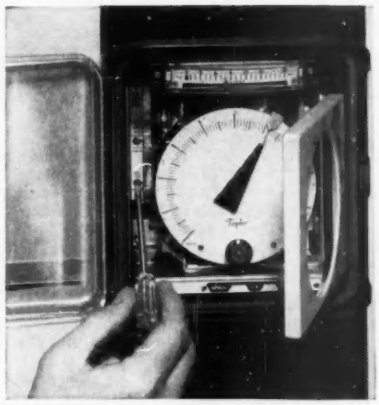
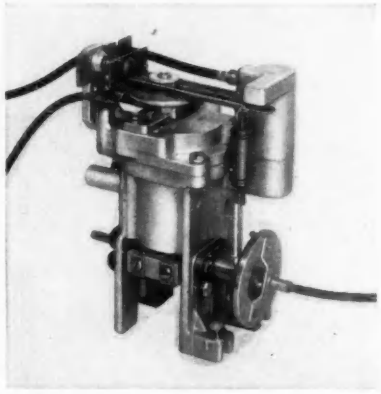
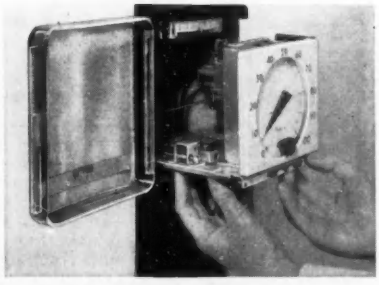


Front of Panel Adjustments. Gain, Reset and Pre-Act* response adjustments can be changed where you see the results while making the change.



Servo-operated Pointers are positioned with 150 times greater power than with conventional bellows, which also permits one or two high-low process alarms—electric or pneumatic.



PLUG-IN Connections. The main slide, including indicator and set point transmitting mechanism, is removed by loosening one holding screw.

Taylor Instruments **MEAN ACCURACY FIRST**

Choosing the Actuator for Linear Feed Hydraulic Servos

C. K. TAFT, Warner and Swasey Co.

Designing linear hydraulic feed or position servos involves choosing either a hydraulic cylinder or a rotary motor with feed screw or rack and pinion. The completed system usually should have the highest possible frequency response with adequate damping. Here are two charts that will help select the proper type of actuator.

HOW TO USE THESE CHARTS

Given V_o, the desired maximum force F_m, and stroke a, select a cylinder area A_c which will supply the maximum force at the desired system pressure. This yields a value of $A_c a/2V_o$. Again on the basis of the static load requirements and the maximum load speed a motor may be selected and the ratio of J_m/J_{LR} determined. The graphs show which system has higher damping ratio and natural frequency.

NOMENCLATURE

A_c = cylinder area, in.²
D_m = motor displacement, in.³/rad
p = screw pitch, rev/in.
n = motor-to-screw gear ratio
ΔP = max pressure across actuator, psi
M_L = load inertia, lb-sec²/in.
J_{LR} = load inertia reflected to motor, lb-in.-sec²
J_m = motor inertia, lb-in.-sec²
B = isothermal bulk modulus of oil, psi
V_o = volume of oil in each line from valve to actuator, in.³
a = total cylinder stroke, in.
K_2 = valve pressure coefficient, in.⁵/lb-sec

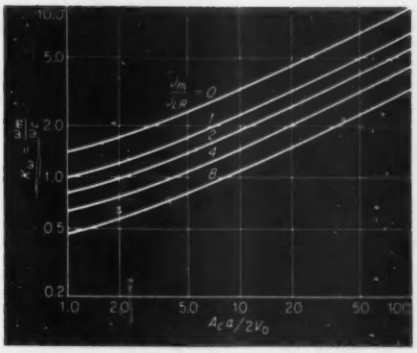


FIG. 1. Comparison of open-loop natural frequencies of hydraulic motor and hydraulic cylinder.

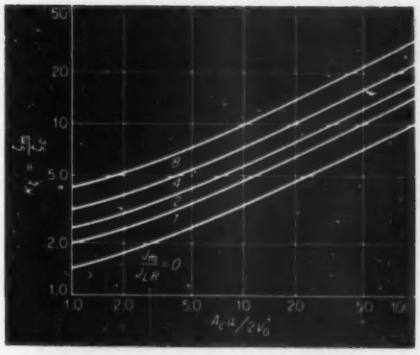


FIG. 2. Comparison of open-loop damping ratios of hydraulic motor and hydraulic cylinder. Motor damping is always better for equal conditions.

DERIVATION OF CHARTS

Assumptions:

1. Supply pressure is constant and equal in both systems.
2. Cylinder is double-acting.
3. Systems use four-way valve much faster than actuator.
4. All friction is small compared to load.
5. Volumes (V_o) of oil in the two lines between valve and actuator are equal.
6. Piston mass is much smaller than load mass M_L.
7. Cylinder position giving lowest natural frequency is compared to motor.

Static Relationships

Maximum load force $= \Delta P A_c = 2\pi \Delta P D_m p n$ (1)
from which $A_c = 2\pi D_m p n$
The load inertia reflected to the rotary motor is:

$$J_{LR} = M_L/(2\pi p n)^2 \quad (2)$$

Dynamic Relationships

Output displacement (c) to valve displacement (x) is:

$$\frac{c}{x} = \frac{K}{s(s^2 + 2\zeta\omega s + \omega^2)}$$

Natural frequencies (ω) for

Motor: $\omega_m = \sqrt{BD_m^2/(J_m + J_{LR})V_o}$

Cylinder: $\omega_c = \sqrt{4BA_c^2/M_L(A_c a + 2V_o)}$

Since system resonance will be generally higher for the actuator with the higher natural frequency, the ratio ω_m/ω_c is a guide to actuator selection.
Substituting from Equations 1 and 2,

$$\frac{\omega_m}{\omega_c} = K_\omega = \sqrt{[(A_c a/2V_o) + 1]/[(J_m/J_{LR}) + 1]}$$

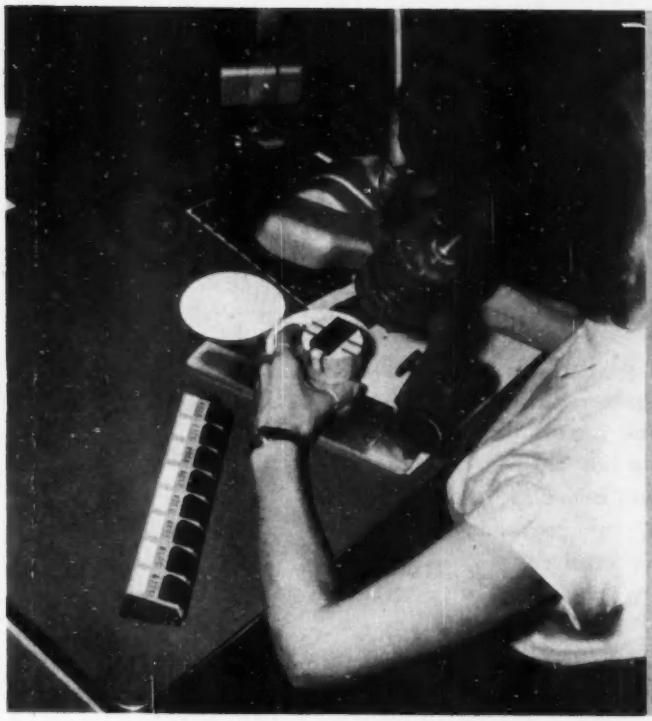
which is plotted in Figure 1.
Similarly, the damping ratios

Motor: $\zeta_m = K_2\sqrt{(J_m + J_{LR})B/8V_o D_m^2}$

Cylinder: $\zeta_c = K_2\sqrt{MB/4(A_c a + aV_o)A_c^2}$

yield $\frac{\zeta_m}{\zeta_c} = K_\zeta = \sqrt{[(A_c a/2V_o) + 1] \times [(J_m/J_{LR}) + 1]}$

which is plotted in Figure 2.



The Veeder-Root VARY-TALLY is a versatile, low-cost reset counter for faster, more accurate hand tallying. Provides positive, easy-to-read record of units, parts, inspection, paperwork, sampling. Available in single units, strips, tiers or any combination.

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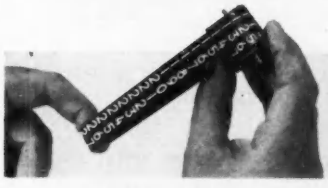

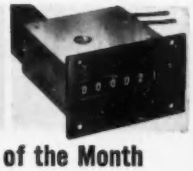

Veeder-Root Counters of the Month

New! 360° Tape-Type Bearing Counter was developed to provide digital readout of angular relationship. Tape greatly reduces size and weight over conventional devices. Adaptable to many indication requirements.

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Better Inertial Indicators for Attitude and Heading

THE GIST: Traditionally, the task of providing a pilot with a visual display of the attitude and heading of his aircraft has been performed by separate inertial instruments—the gyro-vertical or gyro-horizon and the directional or azimuth gyroscope. With the advent of high performance aircraft, however, the trend has been to combine these functions in a single three-axis instrument or stable reference. Here the author describes several methods for providing this mutual stabilization and discusses the relative merits of each.

J. M. SLATER, Autonetics Div.
North American Aviation, Inc.

Before delving into current techniques for combining attitude and heading indication in a single inertial system, it would be well to review the basic problem. The terms attitude and heading refer to the angular relationships between a set of orthogonal airframe axes and a set of orthogonal earth-fixed axes. In Figure 1 the airframe axes (x, y, z) represent the roll, pitch, and yaw axes, while the earth-fixed axes (X, Y, Z) are directed north, east, and downward toward the astronomical nadir, i.e., in the direction of gravity. Two angles completely define attitude: the pitch angle θ between the airframe's x axis and the horizontal plane, and the roll angle ϕ between the xz plane of the airframe and the vertical plane. Heading or azimuth is given by a single angle ψ between the horizontal projection of the x axis and the geographical meridian (X axis in Figure 1). Pitch angle is positive for a nose up condition; roll is positive for a right bank; and heading is positive measured east from north.

Figure 2 illustrates a so-called stable platform, consisting of a stable element mounted in a set of gimbals disposed as indicated, relative to the airframe axes. If the stable element can be made to remain at all times vertical and in the meridian, angles θ, ϕ, and ψ can be read off the gimbals.

A set of three gyroscopes provides the stabilization. These control the gimbals through servosystems by sensing and counteracting any destabilizing effects such as gimbal friction, etc. The type of gyro and servosystem used is immaterial to the present discussion. Nor does it matter whether the gyros are physically attached to a single base or separated in subassemblies slaved to each other about all three axes (X, Y, and Z). To simplify the illustration, Figure 2 shows single-axis gyros and one base.

Since gyros tend to maintain any preset orientation in inertial space (i.e., space defined by the fixed stars), the stable element will, in the absence of controls, sense a total angular velocity ω which is the resultant of rotational velocity of the earth Ω and the angular velocity ω_b of the base about the center of the earth. To keep the stable element vertical and in the meridian, control torques must be supplied to the gyros so that the total precession velocity vector equals the total space velocity vector $\bar{\omega}$.

In terms of a latitude-longitude (λ, Λ) system, components of ω about the X, Y, and Z axes are:

$$\omega_X = (\Omega + \dot{\Lambda}) \cos \lambda \quad (1)$$

$$\omega_Y = -\dot{\lambda} \quad (2)$$

$$\omega_Z = -(\Omega + \dot{\Lambda}) \sin \lambda \quad (3)$$

Signs above are correct for longitude measured east from Greenwich through 360 deg; latitude rate is positive for a craft flying north from the equator. Figure 3 shows a vector representation.

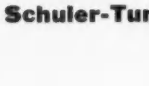
Assuming perfect gyros and perfect data on λ, $\dot{\lambda}$ and $\dot{\Lambda}$, it would suffice to apply these computed compensations to the gyros to provide a perfect attitude and heading reference.

Schuler-tuned System

The terms expressed in the equations above may be derived from sources outside the inertial system (e.g., Doppler radar) or, in one special case, may be generated within the system proper. This special case is the so-called Schuler-tuned inertial system.

In 1923 M. Schuler, a German professor of applied mechanics, noted that a physical pendulum with a length equal to the earth's radius would exhibit a

Schuler-Tuned System . . .



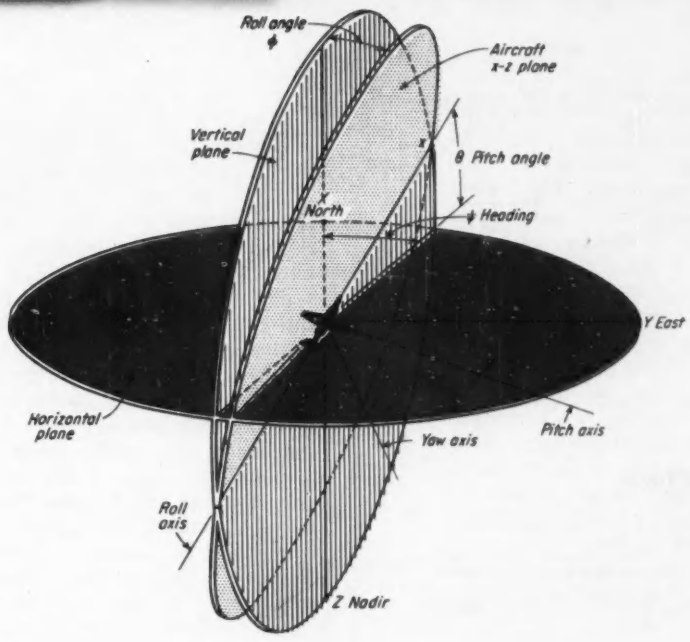


FIG. 1. Eulerian angles relating the airframe axes to the earth-fixed axes.

THESE EXPLAIN THE PROBLEM

unique property: once set vertical, it would remain so even when accelerated over the earth's surface.

The period $T = 2\pi (R/g)^{\frac{1}{2}}$ of such a pendulum is about 84 min for values of R (earth's radius) and g at or near the earth's surface. Although direct mechanization is presently impossible, techniques have been worked out in recent years for providing the virtual equivalent of an ideal Schuler pendulum. Thus, horizontal acceleration can be measured by gyroscopically stabilized accelerometers, integrated with respect to time, and the integrated signal fed back as a control torque to the gyro base, with proper scale factors to impart the desired Schuler period.

Elements of this artificial Schuler pendulum are shown in Figure 4. Associated with the Y-axis gyro is an X-axis accelerometer which senses any velocity change along the meridian. The aircraft is assumed to be flying north or at least to have a northerly component of velocity V_X.

Integration of the accelerometer output a_X provides a computed velocity V_X which is then divided by the radius of the earth R, to give rate of change of latitude $\dot{\lambda}$. A torque proportional to this rate is applied to the output axis of the gyro. This produces an angular precession velocity about the gyro input (Y) axis in accordance with the expression $L = \dot{\lambda}H$, where L is the applied torque and H is the angular momentum of the gyro. Thus, both the gyro and the stabilized accelerometer rotate in space at exactly the same rate $\dot{\lambda}$ at which the aircraft rotates about the center of the earth, and the entire assembly will always remain vertical.

Figure 5 shows two such assemblies added to the uncontrolled stable element of Figure 2. In the right hand subsystem consisting of the X-axis gyro and Y-axis accelerometer, the values a_Y, V_Y, and ω_X include the effects of the earth's rate Ω.

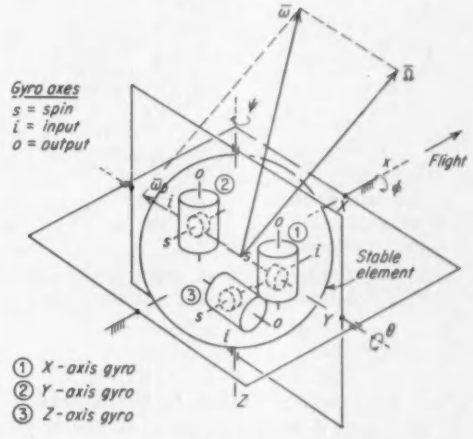


FIG. 2. Uncontrolled stable platform subject to a total angular velocity ω.

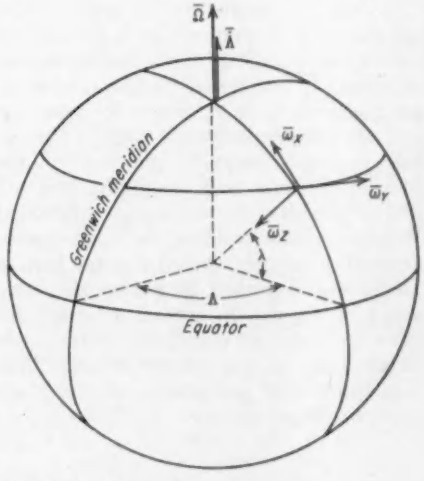
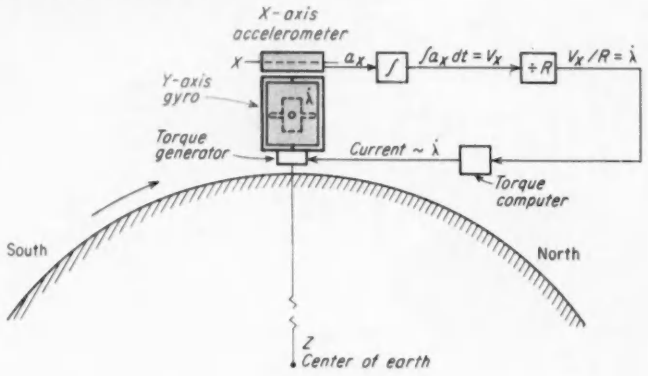


FIG. 3. Angular velocity vector components.

Schuler-Tuned System . . .



. . . Applied to Stable Platform

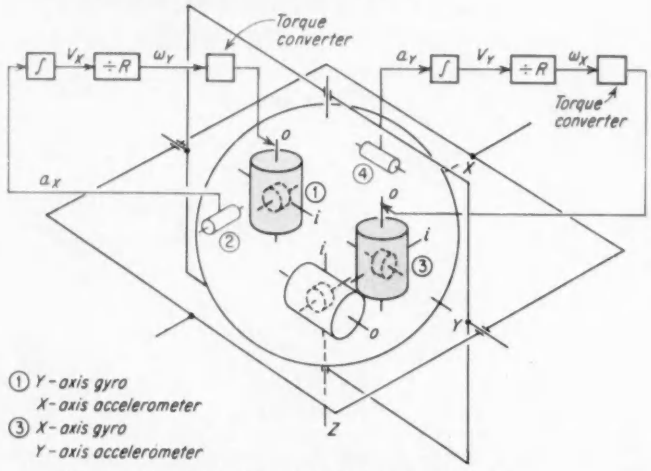


FIG. 4. Basic elements of an artificial Schuler pendulum.
FIG. 5. A Schuler-tuned vertical indication system.

The torques applied to the X- and Y-axis gyros in Figure 5 are proportional to the angular velocity components ω_X and ω_Y. Equations 1 and 2 show that these same components are also proportional to longitude rate and latitude rate. Therefore, information on $\dot{\lambda}$ and $\dot{\Lambda}$ is implicit in the system. If only a vertical reference is required, as is the case with attitude and heading indicators, this information need not be read out. In an inertial navigator, however, a computer would interpret these velocity components in terms of latitude-longitude rates, additional integrators would be used to provide instantaneous values of latitude and longitude, and some form of chronometric device would subtract the earth's rotational velocity from the ω_X component.

Like the ideal physical Schuler pendulum, this system cannot be disturbed by horizontal accelerations caused by changes in ground velocity. Since it functions in a second coordinate system, which rotates at earth rate Ω, it is subject to some disturbance. The horizontal component of the Coriolis acceleration, of magnitude $a_c = 2\,\Omega V \sin\lambda$, for example, could result in a lateral deflection of the indicated vertical from the astronomical vertical. But even in high speed aircraft, this deflection is generally small, and a relatively crude computation and correction will suffice.

In the system described, gyro drift rate and errors in accelerometer bias and integration may produce an oscillation (of 84-min period) but can have no cumulative effect on the vertical indication. For example, a drift rate ω_3 in the X- or Y-axis stabilizing gyro results in an oscillation amplitude of ω_3/ω_4, where ω_4 is the frequency of the Schuler pendulum. Thus a tolerable vertical uncertainty of 0.2 deg corresponds to a tolerable gyro drift rate of about 1 deg per hr. Obviously, construction of a high grade Schuler-tuned vertical reference requires fairly good gyros, but is not unduly difficult in the present state of the art.

While as stated, steady biases will not produce a cumulative error in the undamped system, internal disturbances in phase with the oscillation could produce an intolerable increase in the amplitude of such oscillations on a long flight. In this case, damping of an inertial or noninertial type could be introduced.

The system oscillates because the accelerometer, unable to distinguish between true acceleration and gravity, picks up a component of g proportional to the platform tilt angle; this component, along with the horizontal acceleration, is integrated once in the mechanized velocity computation and a second time by the law of gyroscopic precession in response to the applied torque. This double integration causes the platform to correct its own tilt angle just as a large inertia is centered by a spring. The natural frequency of a Schuler-tuned system is so low that ordinary damping influences have little effect.

Inertial damping amounts in effect to short circuiting the integrator to some degree, i.e., supplying a torque proportional to the measured acceleration as well as its time integral. The single integration by the gyro of the platform tilt component of measured acceleration has the same effect as viscous damping in the spring-inertia system. In the process however, platform tilt angle is also changed by the singly integrated horizontal acceleration component and carried away from the local vertical. As this type of damping is increased, the system becomes more subject to disturbances from horizontal acceleration, and if torque is made proportional to acceleration alone, the system reduces itself to the gravity-erected type of system described later. In the Schuler-tuned system however, this is done only for initial erection.

The system can be damped without becoming vulnerable to horizontal accelerations if some noninertial means of measuring velocity is available, e.g., Doppler radar air speed meters, ground speed meters, etc. This externally measured velocity may be subtracted from the first time integral of the inertially-measured acceleration and the difference applied as an additional torque to the accelerometer.

GRAVITY-ERECTED SYSTEMS

While the Schuler-tuned system would provide an excellent vertical reference in combined attitude-heading indicators, its widest use to date has been in inertial navigation. One reason for this is that the relatively simple gravity-erected systems have proven adequate for use in low performance aircraft and have a limited applicability in some of the more demanding present day applications.

Their limitations, however, are not fully understood. Some have claimed that better gyros will somehow improve the situation, yet in many cases the limitation is in the mode of use and cannot be removed even with perfect gyros. Other claims regarding the performance of gravity-erected instruments simply contradict the laws of motion.

As a source of vertical information, gravity-erected systems use the direction of total acceleration—the dynamic vertical or vector sum of gravity and horizontal accelerations. Gravity represents the "signal", horizontal accelerations the "noise". The three most important horizontal accelerations are:

- acceleration due to ground velocity changes, e.g., acceleration during takeoff and turns,
- short period disturbances from gusts, etc.,
- Coriolis acceleration.

The following two methods of using dynamic vertical signals to establish an approximate astronomical vertical show how horizontal accelerations as well as angular velocity compensation terms are considered.

First Method: A gyro (or set of gyros) is put under servo control from a pendulum, an electrolytic liquid level, or other device that will follow the dynamic vertical. The sensing device, the servosystem, or both are nonlinear and therefore insensitive to gross deviations in direction. The average direction indicated over a given period approaches the direction of the astronomical vertical to the extent that horizontal accelerations average zero in that time.

Second Method: The gyros are put under servo control from a horizontal-acceleration sensing device to which a compensating force can be applied. Horizontal accelerations are measured or computed by noninertial means and a proportional bias applied to the sensing device.

Velocity compensation

Figure 6A illustrates a system using the first method. Although the pendulum and pickoff arrangement simplifies the illustration, an electrolytic liquid level and bridge circuit arrangement is more commonly used in actual practice. In either case these devices are mounted in the stable element and control the torque applied to the gyro axes. If a gyro drifts, giving rise to an off-level signal, torque is applied in such a way as to arrest the drift and tend to restore null conditions. Control rate is limited so that even for large deflections of the dynamic vertical, the gyro goes off very slowly.

In general, low-drift gyros require lower slaving rates, and thereby minimize the error due to transient horizontal accelerations. Of course this is true only if the gyros are simultaneously compensated for angular velocity in accordance with Equations 1 and 2. This involves computations based on ground speed, drift angle, heading, and time.

In both the gravity-erected system and the Schuler-tuned system, the accuracy required of the velocity input data is about the same; yet performance of this

Gravity-Erected Systems

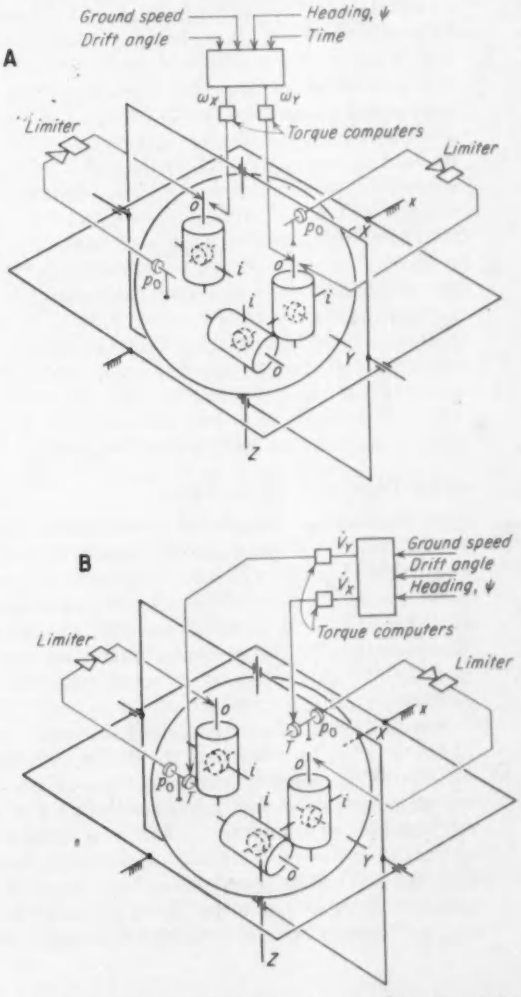


FIG. 6. Gravity-erected vertical references with compensation based A) on angular velocity and B) on horizontal accelerations.

particular type of gravity-erected system is inferior since accelerations are not compensated. For certain less demanding applications, even the velocity compensation is eliminated. In such systems, erection rate is set to saturate at some relatively high value equivalent to the total expected angular velocity. On a fixed base the vertical error can be made as small as desired (regardless of the values of Ω, ω, and gyro drift rate) by simply increasing the erection rate. Cutting off the erection circuit helps some but is scarcely practical in a series of maneuvers.

The acceleration-sensing device on the system described above is a nonlinear direction indicator or null reading device and not a measuring means. Hence direct compensation for disturbing horizontal accelerations is impossible.

Acceleration compensation

The second approach to a gravity-erected system, like the first, makes use of an acceleration-sensing device to which the gyro is slaved. In this case however, the device is designed to accept precise compensation or bias forces which correct for disturbing accelerations. One example of such a device would be a pendulum-pickoff assembly provided with some sort of linear torque generator on its pivot axis.

Figure 6B represents this type of system. Here noninertial equipment computes the horizontal accelerations. Inputs to the compensation computer include ground speed, drift angle, and heading. The computed acceleration is resolved into components along the X and Y axis. Proportional bias torques are then applied to the pivot axes as shown.

Ideally the gyros should be velocity compensated as in Figure 6A, in which case their maximum slaving rate could be limited to a low value. In practice however, if the acceleration compensation is really effective, the slaving rate can be increased to the point where velocity compensation is unnecessary. Then gyro drift rate becomes unimportant, and there is no point in using precision gyros.*

MAINTAINING HEADING

In the systems considered so far, it has been assumed that the Z-axis gyro maintains the heading of the stable element. This too requires certain compensation techniques. With a perfect azimuth gyro, perfectly stabilized, it would be sufficient to apply compensation for the ω_Z term. Such data could be provided by the computer of an inertial navigator or Doppler radar system.

Any drift rate of the gyro itself, however, would appear as a heading drift rate $\dot{\psi}$. Faulty stabilization would produce a similar effect due to cross coupling; a component of aircraft angular velocity ω_b or of Ω might appear as a spurious $\dot{\psi}$. Errors in computation of the ω_Z term would likewise appear as a heading drift rate. Thus an open-loop system, to provide an accurate heading reference ($\dot{\psi}$ of from 0.1 to 1.0 deg hr), would require a rather high order of accuracy in the gyro itself, in the stabilization system, and in the computer.

There exists no generally applicable method for limiting heading error to an acceptably low value. For example, there is no physical vector quantity aimed at the north pole equivalent to the gravity vector aimed at the center of the earth. Certain techniques, however, may be useful.

First, the azimuth gyro could be slaved to a magnetic compass. This restricts heading to some extent but usually within limits which are too wide for most applications.

A second approach, the gyro-compass mode of operation, gives excellent results in shipboard applications but is generally not applicable to aircraft. A gyro-compass is essentially a device for locating a horizontal axis about which space angular velocity equals zero. At a fixed point on the earth, such axis is oriented east-west or normal to the earth's axis of rotation. On a base moving around the center of the earth at angular velocity ω_b, such axis is normal to the vector direction of ω_b; i.e., unless the aircraft is traveling east or west, this axis cannot be normal to the earth's rotational axis. In the case of a ship, ω_b is always small and compensation can readily be made. In an aircraft on the other hand, ω_b can be of the same order as Ω. Thus compensation for ω_b requires, in effect, very accurate knowledge of aircraft velocity, even when ω_b is substantially less than Ω. Moreover if ω_b equals Ω, the whole principle of the operation can break down; e.g., in an aircraft heading east at such speed, the total sensed angular velocity is zero and the compass becomes neutral.

It should be noted, however, that the gyro-compass technique can be very useful in aligning a three-axis stable reference on the ground before flight. The Y-axis gyro (the one used for level stabilization about the east-west axis) performs the gyro-compass function and must be very good, not only as regards uncertainty drift rate but also as regards absolute drift rate, since a constant but unknown drift rate results in a constant heading error.

If a Doppler radar system is available, a fairly elegant system combination becomes possible. On the one hand, the Doppler radar can measure ground speed and drift angle quite accurately, but requires a first-class inertial heading reference to resolve this information in terms of geographical velocity components. On the other hand, a precision gyro can furnish a first-class heading reference, provided the necessary velocity information is available. An appropriate computer, including a chronometric device to take care of the earth's rotational velocity Ω, could for example supply the necessary compensation to the azimuth gyro in the Schuler-tuned system of Figure 5. Overall performance of this combination would be exceptionally good.

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* *U. S. Patent 2608867, to S. Kellogg et al, describes an interesting approach to mechanization of this type of system.*

Evaluating Control System Payout From Process Data

THOMAS M. STOUT
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THE GIST: Before investing in the control equipment, the user must be assured the proposed system offers promise of satisfactory payout. After installation he must verify that an improvement does indeed result from the control system. Such assurance can be obtained by use of a mathematical model in combination with actual operating data. The model permits calculation of the benefits to be expected, and a statistical analysis of process data indicates how much confidence can be placed in the estimates.

Since a small percentage improvement can be important on a dollar basis, the expected benefits must be determined with a high degree of reliability. Careful analysis makes certain that the benefits are real and not a result of random measurement errors or a chance selection of data. Reliable results are obtained by expending time, effort, and money to collect essential information.

A common problem in justifying new control schemes might be called the Before and After Problem. *Before*, using conventional temperature control, a chemical reactor produces 600 barrels per hour of product. *After* introducing an infrared analyzer into the loop, cascaded to the temperature control, production rate increases to 660 barrels per hour. Is stream analyzer control really better than environmental control?

The question arises from the possibility—or rather the certainty—that the numbers are in some way inaccurate. The production rates may have been measured with different instruments or by different persons, and the process feed flow rates may not have been exactly the same in both runs. Even if such obvious sources of difficulty as these have been avoided, other and more subtle influences have undoubtedly affected the results. Thus, while the hoped-for result occurred, was it a matter of chance or a real effect?

To answer this question requires more data and some statistical analysis. To see what information is needed and how it is used, consider a specific problem of current importance: the evaluation of a computer control system.

Justifying a control system

The justification for investment in any new control equipment, whether it is a computer control system, a stream analyzer, a radiation thickness gage, or the like, is based on dollar earnings resulting from some combination of increased production, better quality, and reduced operating costs. If the necessary information is available, it is possible to estimate in advance the earnings that can be expected. By relating these estimates to new equipment costs, a payout time or return on investment can be calculated. The relative attractiveness of various investments can then be weighed.

In designing a computer control system, relationships—mathematical models—are usually developed which permit prediction of optimum behavior under varying process conditions. The same relationships can be used to estimate the expected earnings from the computer control system. The usual procedure is to collect actual process data for some recent, rep-

TABLE I
MEASURED PRODUCTION RATES BEFORE CONTROL SYSTEM INSTALLATION

Time	Measured production rate (P)	$P - P_{avg}$	$(P - P_{avg})^2$
0100	8,480	475	225,625
0200	8,500	495	245,025
0300	8,430	425	180,625
0400	8,580	575	330,625
0500	8,350	345	119,025
0600	8,250	245	60,025
0700	8,050	45	2,025
0800	8,000	−5	25
0900	7,870	−135	18,225
1000	7,750	−255	65,025
1100	7,600	−405	164,025
1200	7,490	−515	265,225
1300	7,470	−535	286,225
1400	7,700	−305	93,025
1500	7,370	−635	403,225
1600	7,570	−435	189,225
1700	7,650	−355	126,025
1800	7,750	−255	65,025
1900	8,070	65	4,225
2000	8,000	−5	25
2100	8,080	75	5,625
2200	8,150	145	21,025
2300	8,450	445	198,025
2400	8,510	505	255,025
Total =	**192,120**	**0**	**3,322,200**
Average =	**8,005 = P_{avg}**		

TABLE IA
SHORT TERM MEASURED PRODUCTION RATES

Time	Measured production rate (P)	$P - P_{avg}$	$(P - P_{avg})^2$
0756	8,000	14	196
0757	7,960	−26	676
0758	8,100	114	12,996
0759	8,040	54	2,916
0800	8,000	14	196
0801	8,000	14	196
0802	7,900	−86	7,396
0803	8,000	14	196
0804	7,940	−46	2,116
0805	7,920	−66	4,356
Total =	**79,860**	**0**	**31,240**
Average =	**7,986**		

resentative period of operation. Applying the optimizing relationships to the actual operating data, the optimum production rate, product quality, or operating cost for computer control is calculated. The computed production rates, for instance, are then compared with the corresponding production rates from actual process operation. If economic benefits are enough, there is justification for installing a computer control to carry out the optimizing procedure on which the justification is based.

After installation, actual operating data on computer performance is available, and these figures can be compared with those obtained during previous operation without the computer. The comparison does not provide a direct check on the mathematical relationships used to make the earlier estimates because the present conditions will not be identical with those used in justifying the investment. However, because the comparison is based on measured process performance, it gives a more reliable indication of the earnings actually being obtained.

Assume the computer control system is designed primarily to increase production and that four sets of data become available:

Table I–Measured production rates, units per hour, for a 1-day operating period.

Table IA–Measured production rates, units per hour, for a 10-min period.

Table II–Calculated production rates for the same period, giving the best attainable production rates for the same feed rates and compositions, catalyst activity, cooling water temperature, etc.

Table III–Measured production rates, for similar but not identical conditions, for a 1-day period following installation of a computer control system.

Analyzing the "before-measured" data

Table I shows the total production for the day was 192,120 units, so the hourly average was 192,120/24 = 8,005 units. How reliable is this number?

To specify the reliability of an average, the reliability of individual readings must first be determined. The natural step would be to compute a standard deviation from the data in Table I. Some necessary calculations are, in fact, presented in the table. The apparent standard deviation is:

$$s_P = \left[\frac{\Sigma (P - P_{avg})^2}{N - 1}\right]^{\frac{1}{2}}$$

$$s_P = \left[\frac{3{,}322{,}200}{23}\right]^{\frac{1}{2}} = 380.1$$

As can be seen from the $(P - P_{avg})$ column, the production rate is systematically higher at night than during the day. This effect might be due to a decrease in cooling water temperature. Using the mathematical model, corrections could be made for this and other known sources of variation, leaving values showing random variation about the average.

The reliability of the average production rate, 8,005 units, cannot be judged from the calculated standard deviation (S_P = 380.1) which includes both systematic and random variations. The need for some kind of allowance for this fact can be seen by imagining the production rate to follow a sine curve and to be measured exactly; here the average production rate can be stated exactly even though the standard deviation of individual points about the average might be far from zero. To isolate the random variations, repeated measurements of production rate can be made during a very short time interval ap-

proximating essentially fixed processing conditions. Such measurements are shown in Table IA. The corresponding standard deviation is:

$$s_P = [(31{,}240)/(10 - 1)]^{\frac{1}{2}} = 58.9$$

This new, smaller standard deviation will be taken as a measure of possible variation in any single observation of the production rate. According to basic probability theory, if the errors are normally distributed, then about two-thirds of the measurements can be expected to have an error less than one standard deviation. Thus two-thirds of the hourly production rate measurements will have an error not exceeding 58.9/7,986 or 0.74 percent. Likewise, almost all hourly measurements should be within three standard deviations, or $3 \times 0.74 = 2.22$ percent.

The standard deviation of the average production rate over a 24-hr period is:

$$s_{P\ avg} = s_P/N^{\frac{1}{2}} = 58.9/24^{\frac{1}{2}} = 12.0$$

Hence, while the individual hourly production rates might be in error by as much as 2.22 percent, it can be safely said that the daily average rate was within the limits:

$$8{,}005 - (3 \times 12) \text{ and } 8{,}005 + (3 \times 12)$$
$$\text{or } 7{,}969 < P_{avg} < 8{,}041$$

This is a spread of plus or minus 0.45 percent. (The standard deviation based on random average of hourly readings for a week is $s_{P_{avg}} = 4.54$ and for a year is $s_{P_{avg}} = 0.63$. Thus, the greater the number of data points, the greater the confidence that can be placed on the calculated average.)

Analyzing the "before-calculated" data

Using the mathematical model developed to represent the process, the calculated production rates for the same period are those given in Table II. How good is the calculated average of 8,244 units, and how good are the individual production rates?

Unless the mathematical model has previously been checked experimentally, its reliability must be estimated from theoretical considerations. The model is the expression of the production rate as a function of process variables:

$$P_{calc} = f\ (v_1, v_2, v_3, v_4, \ldots)$$

The standard deviation of a function of several variables is approximated by the expression (Ref. 1):

$$(s_{P\ calc})^2 = \left(\frac{\partial P_{calc}}{\partial v_1}\right)^2 (s_{v_1})^2 + \left(\frac{\partial P_{calc}}{\partial v_2}\right)^2 (s_{v_2})^2 + \left(\frac{\partial P_{calc}}{\partial v_3}\right)^2 (s_{v_3})^2 + \ldots \quad (1)$$

where $\partial P_{calc}/\partial v_i$ is a partial derivative measuring the effect of the ith variable on the production rate, and s_{v_i} is a standard deviation measuring the uncertainty in the value of the ith variable. In general the partial derivatives will be different for the individual variables and will not be known exactly but have been determined to some extent by analysis of process operating data. Likewise, the standard deviations will be different. For the present hypothetical case, there is no particular benefit in stating values for the partial derivatives and standard deviations of the variables. The result would merely be some arbitrary value of s_{Pcalc}.

TABLE II
CALCULATED PRODUCTION RATES
BEFORE CONTROL SYSTEM INSTALLATION

Time	Calculated optimum production rate (P_{calc})
0100	8,640
0200	8,870
0300	8,630
0400	8,730
0500	8,880
0600	8,280
0700	8,490
0800	8,260
0900	7,940
1000	8,200
1100	7,710
1200	7,550
1300	7,930
1400	7,740
1500	7,750
1600	7,640
1700	8,130
1800	7,900
1900	8,110
2000	8,250
2100	8,290
2200	8,220
2300	8,740
2400	8,980
Total	**197,860**
Average	**8,244**

However, it would seem reasonable that s_{Pcalc} should be greater than s_P, since the calculated production rate depends on some uncertain partial derivatives and on a number of process measurements instead of just one measurement for the actual production rate. (This condition may not exist, however, if the variables with the large standard deviations have only slight influence on the production rate.) For purposes of illustration, assume that Equation 1 gives:

$$s_{P\ calc} = 80 \text{ units}$$

Thus two-thirds of the calculated, random, individual production rates are expected to be within 80 units of the true value, and very few of them should be inaccurate by more than 240 units.

The standard deviation of the calculated average production is:

$$s_{P\ calc\ avg} = 80/24^{\frac{1}{2}} = 16.3$$

The difference between the two average production rates is:

$$\Delta P_{avg} = P_{calc\ avg} - P_{avg}$$
$$= 8{,}244 - 8{,}005 = 239$$

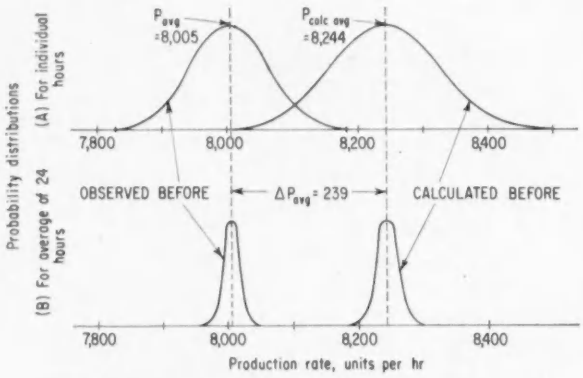

FIG. 1. Before computer control system installation, plots of measured and calculated optimum production rates indicate the production rate can be increased by an estimated 239 units per hour. The reduction in overlap arising from averaging over a 24-hr period adds confidence to the estimated improvement.

Then, according to Equation 1, its standard deviation is:

$$(s_{\Delta P\ avg})^2 = (s_{P\ calc\ avg})^2 + (s_{P\ avg})^2 \quad (2)$$

$$= (16.3)^2 + (12.0)^2 = 409.8 \quad (3)$$

$$(s_{\Delta P\ avg}) = 20.2 \text{ units} \quad (4)$$

(Strictly speaking, the difference between two averages is not normally distributed but fits a *t*-distribution curve. Such distributions define the probability of a given error occurring when the number of data points from which the error is determined is small, as compared with a normal distribution curve which assumes an infinite number of random data points. The *t*-distribution has a greater spread than the normal distribution. However for the present case employing many points, the two distributions are almost identical.)

The ratio of the observed difference in production rate to the standard deviation

$$t = \Delta P_{avg}/s_{\Delta P} = 239/20.2 = 11.8$$

is so large that it could scarcely have occurred by chance. Said another way, the large *t*-value means that in this case the indicated improved production rate is indeed due to the optimizing relationships. The calculated increase in production rate has a high probability of lying between:

$$239 - (3 \times 20.2) = 178 \text{ and } 239 + (3 \times 20.2) = 300$$

To be conservative, the justification for buying the system could be based on an economic benefit corresponding to the smaller figure, 178 units per hr, but it would be quite reasonable to use the calculated increase of 239 units per hr.

Figure 1 imparts a clearer idea of the meaning of these calculations. The upper graph shows the estimated probability distributions for individual hourly production rates (corrected for systematic variations), and the lower graph shows the probability distribution for daily average production rates. The best estimates of the average production rate before installation of the computer control system and what it is expected to be after installation are 8,005 and 8,244 units, respectively.

Figure 1 shows that, because of the various uncertainties in the measured data and the mathematical model, the distributions for individual hours overlap. For any given hour, there is some chance that a calculated maximum production rate will be less than the corresponding measured less-than-maximum value. The lower graph shows that the effect of averaging 24 hourly rates is to reduce the overlap, the reduction being so great that in this case the overlap essentially disappears. If the comparison had been based on fewer data, say averages for only four hours, the overlap would not have been eliminated, and the increase in production rate could not be claimed with as much assurance.

Analyzing the "after-measured" data

Assuming the expected value of the increased production rate of 239 units per hr proves profitable with respect to the cost of purchasing, installing, and maintaining a computer control system, the control system is installed to duplicate the optimizing procedure on an automatic basis. Following installation, it is observed that the production rate is indeed increased. A typical day's log, Table III, shows an average production rate of 8,269 units for processing conditions similar to those existing at the time the data in Table I was collected. Is the production improvement real? What does the actual process data taken when the computer is operative reveal about the accuracy of the mathematical model?

The difference in the observed average production rates, from Tables III and I, is:

$$\Delta P_{avg} = 8{,}269 - 8{,}005 = 264 \text{ units}$$

If the random variations in the production rates are the same as before, the standard deviation of *this* difference is:

$$(s_{\Delta P})^2 = 12^2 + 12^2 = 288$$

$$s_{\Delta P} = 17.0 \text{ units}$$

The ratio of the observed difference to the standard deviation:

$$t = 264/17 = 15.5$$

is even bigger than in the previous case. The difference in observed production rates is evidently real.

Checking the accuracy of the mathematical model requires first calculating the expected production rates for the actual processing conditions existing when Table III was logged and then comparing the computed rates, on an hour-by-hour basis, with the measured production rates in Table III. Assume the calculated optimum production rate is 8,294 units, with an hourly standard deviation of 80 units, and a daily-average standard deviation of 16.3 units. The difference in the calculated and measured optimum rates is:

$$\Delta P_{avg} = 8{,}294 - 8{,}269 = 25$$

With a standard deviation of 20.2 units (from Equations 2–4), it can be said that the actual difference probably falls between:

$$25 - (3 \times 20.2) = -35.6 \text{ and } 25 + (3 \times 20.2) = 85.6$$

The ratio of the difference to its standard deviation is:

$$t = 25/20.2 = 1.24$$

According to an appropriate table for the *t*-distribution (Ref. 2), a difference of the observed magnitude or greater would occur about one time in four if both the actual and calculated production figures were drawn from a single distribution. While a one-in-four probability suggests the computer control system does not follow the mathematical (optimum) model too well, the evidence is not too strong, and additional data should be collected before any revisions of the computer program or other control equipment are attempted.

Ideally, production rates calculated using the mathematical model would exactly match the rates measured in the process, and the corresponding probability distributions would coincide. Likewise, the calculated and observed averages over any time period would be identical.

For the present case, Figure 2, a plot similar to Figure 1 but showing the distributions of the observed and calculated production rates after a computer control system was installed, indicates only partial overlap of the hourly distribution curves. However, some overlap is shown even for the averages over a 24-hr period, verifying that the observed process performance follows the mathematical model fairly faithfully.

TABLE III
MEASURED PRODUCTION RATES
AFTER CONTROL SYSTEM INSTALLATION

Time	Measured production rate (P)
0100	8,720
0200	8,940
0300	8,550
0400	8,770
0500	8,730
0600	8,210
0700	8,530
0800	8,180
0900	8,820
1000	8,190
1100	7,630
1200	7,530
1300	8,030
1400	7,730
1500	7,740
1600	7,740
1700	8,050
1800	7,820
1900	8,100
2000	8,230
2100	8,270
2200	8,240
2300	8,720
2400	8,990
Total	**198,460**
Average	**8,269**

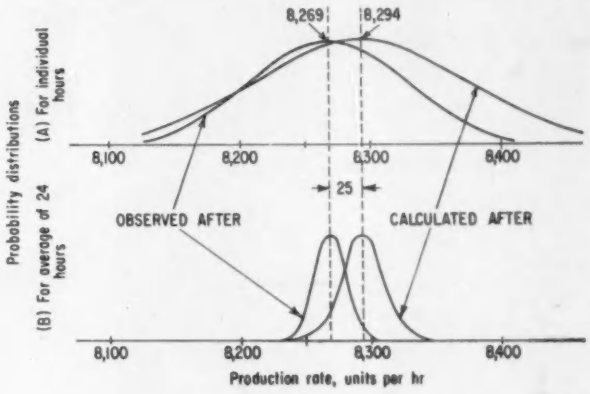

FIG. 2. After computer control installation, the plots verify that the system did increase production and that, because of the considerable overlap, the computer optimizing model matches mathematical optimizing model fairly well.

In books on statistics, the phrases "almost all", "very few", "scarcely", "high probability", and other similar expressions relating to the probability distributions are given a quantitative interpretation. For example, "a variable fitting the *t*-distribution with 10 degrees of freedom has a 99 percent probability of falling 1.81 standard deviations or less from its mean value." Such precision was not considered to be justified in the examples given in this article because the standard deviation of the calculated production rates was a mere estimate. In actual process studies, where a more exact value is obtainable, greater significance can be attached to the figures in the statistical tables.

Sound estimates of expected benefits from installation of a computer control system can be made if adequate information is available. This information includes measures of the random variations in measurements of the process variables and a mathematical model of the process. Whether the evaluation is based on pre-installation calculations or post-installation measurements, its reliability depends directly on the number of data points employed. As usual in statistical studies, any desired degree of confidence can be achieved by expending enough time, money, and manpower.

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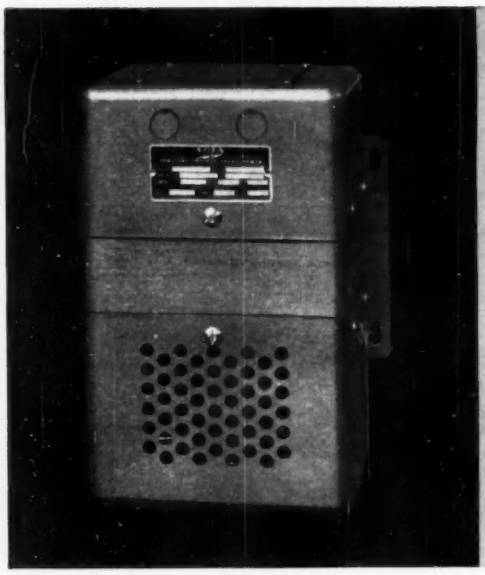


Sola Sinusoidal type Constant Voltage Transformers for universal application, now moderately priced

Housed unit with mounting plate typical of structures employed in 60va to 1kva ratings.

Price reductions extend scope

An important advance in the field of voltage regulation is the development of a new line of Sola Standard Constant Voltage Transformers with sinusoidal output. New design enables us to price them about the same as previous models not having sine-wave output. Now you can have the advantages of ±1% static-magnetic voltage regulation in new applications requiring harmonic-free input where previously the cost was a deterrent.

These new units provide output voltage regulation of ±1% for line voltage variations as great as ±15%. They regulate automatically and continuously. Fast response time averages 1.5 cycles or less. Output has less than 3% total rms harmonic content, and formulae based on sinusoidal wave shape may be used in designing related load circuitry.

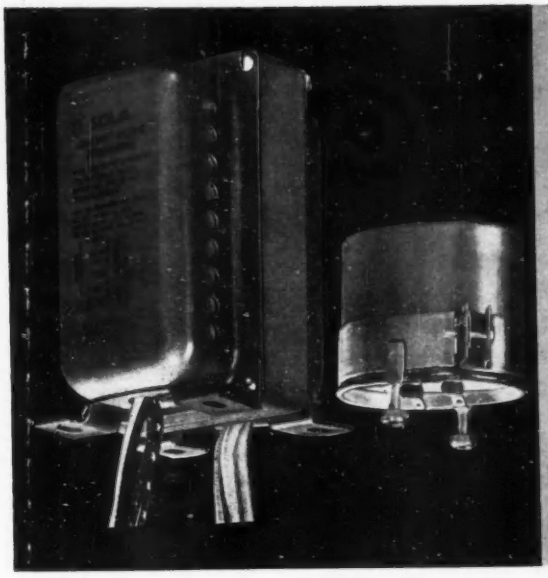
Design and production innovations make these new units substantially smaller and lighter than previous models. They are relatively compact compared to other equipment for comparable ac voltage regulation. They are easy to select and order —the buyer merely selects the stock unit whose output capacity equals or exceeds the desired equipment input. Sola Standard Sinusoidal CV Transformers are available in nine stock output ratings from 60va to 7500va. Custom designs to meet specialized requirements are available in production quantities.

Write for full information . . .

With electrical control systems and components continuing to increase in number and complexity, and imposing more rigid reliability requirements, these new Sola Constant Voltage Transformers provide many advantages and virtually unlimited application. They are the result of over four years of development, design, and production engineering in the Sola laboratories and plant.

These developments mean superior voltage regulation, giving you a bonus in equipment reliability and performance at no increase in cost.

For full information, please write for technical literature on Sola Constant Voltage Transformers. We will mail it promptly, or if you wish, we will have a representative call on you.



Sola Normal-Harmonic type Constant Voltage Transformers now specifically designed and priced for component use

End-bell unit with separate capacitor typical of structures engineered for component use.

# of Sola voltage regulation

Re-design of Sola "Normal-Harmonic" type static-magnetic voltage regulators has resulted in a significant reduction in their size and weight. Prices on many of these units have been reduced. Now it's possible for you to improve equipment performance by using them in many new fields at less cost than ever before. Re-design has in no way sacrificed the performance of these units—they provide all the outstanding benefits which have made them the standard of the industry for more than fifteen years.

Sola Normal-Harmonic type voltage regulators provide ±1% output voltage with line voltage variations as great as ±15%. This group has an average of 14% total rms harmonic content in its output voltages and is suited to equipment not extremely sensitive to voltage wave shape.

Sola Normal-Harmonic type voltage regulators are available in nineteen stock ratings from 15va to 10kva, including those mechanical designs specially engineered for use as built-in components. With many of the most popular ratings now reduced in price, these Sola Constant Voltage Transformers provide one of the most economical means of close voltage regulation in a broad range of applications.

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Techniques of Dynamic Display

Part I: Cathode Ray Tubes

To put up-to-date information in the hands of human operators of control systems when the information continually changes at a high rate is the function of the dynamic display equipment, newly developed to overcome the shortcomings of conventional display hardware. This is the start of a three-article series which describes new display techniques and hardware. Part I is limited to Cathode Ray Tube Displays.

RICHARD A. BARKER
Stavid Engineering, Inc.

Dynamic display—the exhibit of information which continually changes, sometimes at high rates of speed—attempts to overcome the limitations of conventional display hardware. These deficiencies make up seven categories: 1) size, 2) brightness, 3) currentness, 4) freedom from objectionable psychological effects, 5) resolution, 6) quantity of information presented, and 7) pictorialism. Not all of the conventional display approaches are deficient in all of these categories; neither does any dynamic display technique satisfy all seven in an optimum manner. Rather, dynamic display techniques generally improve one or several of these limitations.

Development work to date falls in three broad fields: 1) modification of cathode ray tubes, 2) optical techniques, and 3) special techniques such as television pickup and transfer, character display, drum storage systems, and matrix cell techniques (solid state, like electroluminescence; liquid, like Electroflors; and gaseous).

Because so many of the applications for dynamic information are associated with electronic systems—air traffic control, air defense, battlefield surveillance, and high speed data processing—considerable effort has been expended on making the cathode tube a more useful display device. The results are classed in five groups:

1) character generation tubes
2) direct view storage tubes
3) scan conversion tubes
4) color tubes
5) special function tubes

Some of the newest and most useful techniques are tabulated on pages 103 to 105, along with how they work, their advantages, limitations, and suppliers. Some are still in the development stage.

Selection of a display technique depends primarily on the specific problem to be solved: need for a larger display, brighter display, more information storage, etc.

Character generation tubes

To identify as well as display information, character generation tubes have been developed. These are tubes that can generate one or more numeric, alphabetic, or alphanumeric letters by passing the electron beam through an appropriately shaped aperture. Some of these have been available for several years. The Charactron tube, for example, can generate both analog and alphanumeric information (up to 64 characters). It is now available in large sizes, is capable of a resolution in excess of that of the human eye, and has a life expectancy of 5,000 hours.

Character-type information on cathode ray tubes is generated by one of three methods: the raster scan, Lissajous, or the shaped beam. In the raster scan technique the intensity of the electron beam during the sweep is controlled. The characters are generated in segments in much the same manner employed in facsimile recording. In the Lissajous method the electron beam is used as one would use a pencil; a combination of intensification and deflection obtains the desired shape. In the shaped beam approach, a series of stencil-like openings within the tube are used to shape the electron beam into the proper configuration.

These tubes make it possible to generate electronically an identifying over-lay on a conventional display such as a plan position indicator (PPI), using time-sharing. By using a modification such as a two-gun Charactron tube, however, the radar display and the character presentations can be generated independently.

Other character generation tubes are the Typotron, which combines character presentation with storage; the Compositron, which can display several thousand letters per sec; and the Indicoder which displays a limited number of characters (up to 12) one at a time.

Direct View Storage Tubes

Long persistence phosphors are not bright enough for many applications. The direct view storage tube offsets this deficiency by holding information on the tube face. A "write" electron gun deposits intelligence on a storage mesh. A "flood" electron gun then excites a phosphor screen following the pattern on the mesh.

Capabilities of these tubes range widely. Displays can be stored for periods that range from 60 sec in the RCA 6866 tube to several days in the Hughes Memotron. Writing speeds: as high as 300,000 in. per sec.

Scan Conversion Tubes

Electronic information produced in a form which is not suitable for display can be converted to a form that is. One way to do this is the scan conversion tube. Although the scan conversion tube is not a display device itself, its use as a tool of display warrants its inclusion in this survey. Probably the best known application of this technique is the conversion of radar blips, normally seen on a PPI display, to a TV signal viewed on a television screen. Because information can be put into a scan conversion tube at one rate and withdrawn at another, the device affords a certain amount of storage. In air traffic control the device retains aircraft location so a dotted trajectory appears on the TV screen.

Best known o fthe scan conversion tubes is the Intec video transformation tube, of which 70 are already in use, primarily in air traffic control work. Other scan conversion devices are the Graphecon, the Radechon, the Day tube, and the Recording Storage Tube. The Intec tube, the Graphechon, and the Day Tube are double ended devices—information enters one end, is converted and/or stored, and is delivered at the other. The Radechon is a single ended tube which requires time-sharing of the writing and reading functions. The Recording Storage Tube is designed for indefinite storage of information—up to hours. Information can be read out as many as 30,000 times without deterioration.

Color Tubes

The use of color in displays offers one of the most promising ways of displaying several variations in information at the same time. For example, it might be possible to display radar blips representing aircraft at the same altitude in one color, aircraft at another altitude in a second color, etc. Many color tubes under study were developed for entertainment television but may find biggest uses in industry and the military.

Special Tubes

Some of the most interesting developments in display have occurred in the introduction of radically different cathode ray tubes, of which the Aiken tube, or flat cathode ray tube, appears among the most promising. In addition to reducing the size of the display tube, the flat cathode ray tube is three times as bright as a conventional CRT, has 20 times the focusing power. Modifications under development include a two-color tube, a three-dimensional display tube, a polar coordinate display, and a character generating flat tube.

Another unusual development is the Skiatron, a dark trace tube which makes projected displays clear and sharp. Other special developments are the light valve tube which projects a deposited display, and a large (30-in.) cathode ray tube.

HERE'S WHAT SOME OF THEM LOOK LIKE

CHARACTER GENERATION TUBES

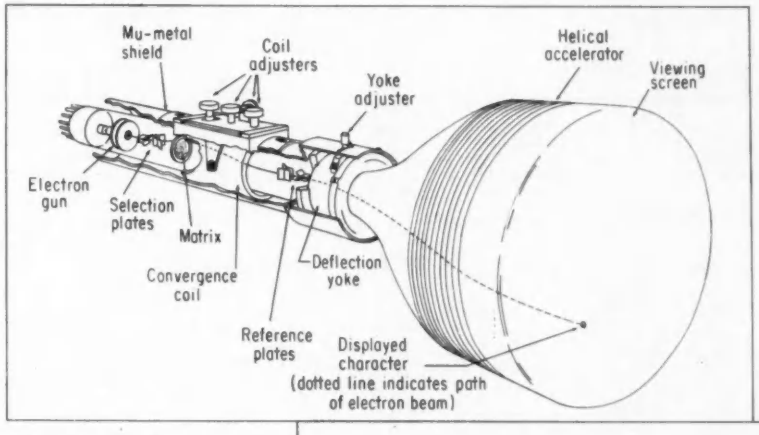

FIG. 1 Charactron

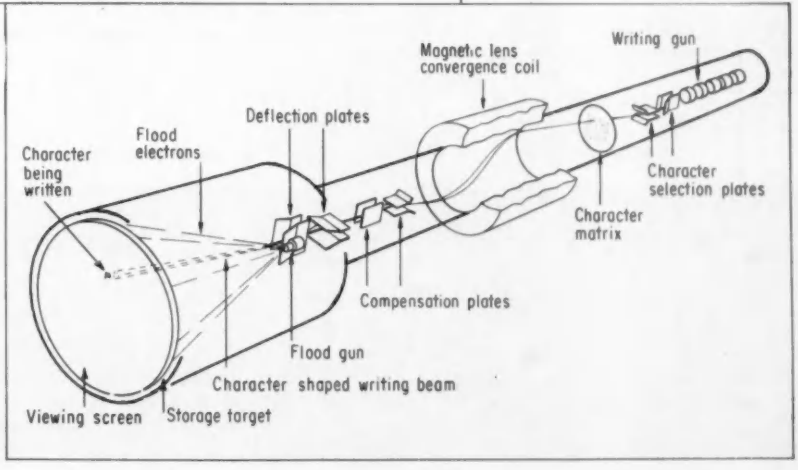

FIG. 2. Typotron

DIRECT VIEW STORAGE TUBES

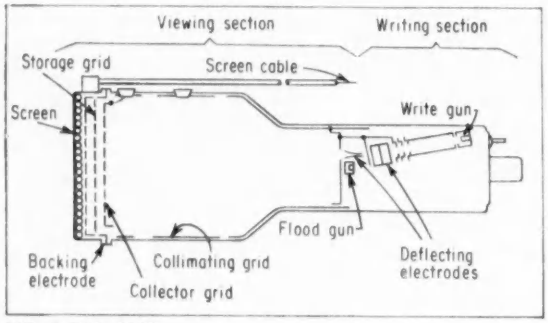

FIG. 3 RCA 6866

COLOR TUBES

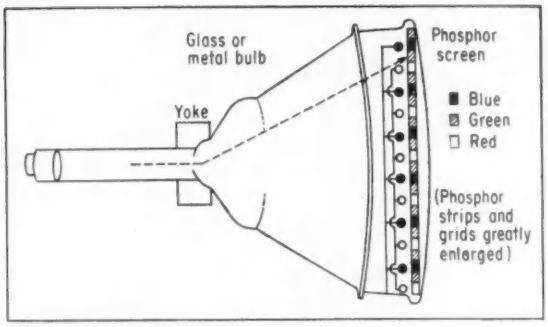

FIG. 6. Chromatron

SCAN CONVERSION TUBES

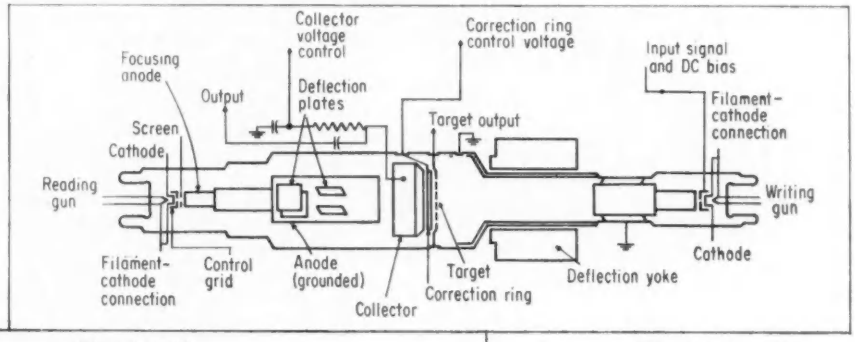

FIG. 4. Intec Video Transformation TMA-403X

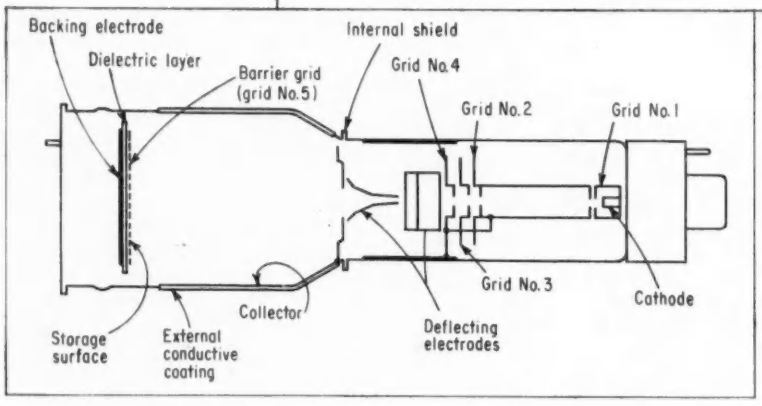

FIG. 5. Radechon

SPECIAL TUBES

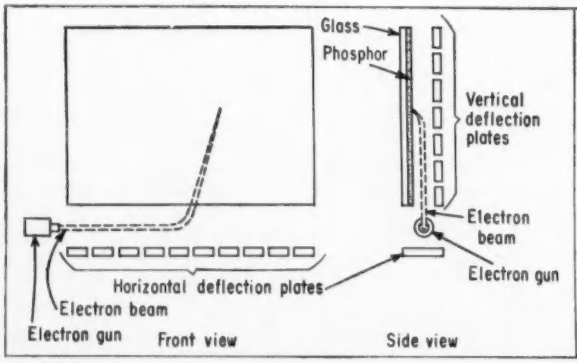

FIG. 7. Aiken

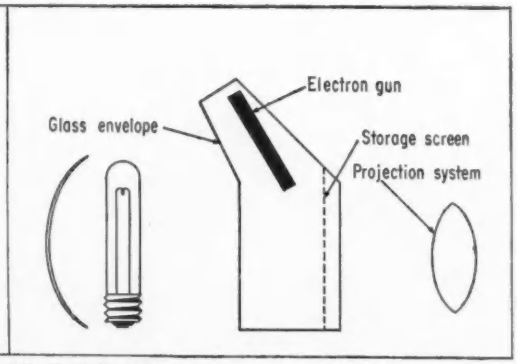

FIG. 8. Light Valve

CATHODE RAY TUBE DYNAMIC DISPLAY TECHNIQUES

TYPE OF DISPLAY	KEY FEATURES	APPLICATIONS	ADVANTAGES	LIMITATIONS	SUPPLIER
CHARACTER GENERATION TUBES	**Identification as well as display of information by this cathode ray tube which can present one or more numeric, alphabetic, or alphanumeric characters at the same time. Generation can be by raster scan, Lissajous, or the shaped beam.**				
Charactron	The tube has a 19-in. diagram screen and is used for visual displays. The heart of the tube is the beam-forming matrix; there are 64 characters arranged in an 8 by 8 format. Tube with 17-in. diameter usable face costs about $1,600. (See Figure 1.)	Can display alphanumeric symbols and analog data concurrently. In most applications a display rate of approximately 10,000 characters per sec is used. Depending upon the system parameters, a rate up to 20,000 characters per sec is attainable.	The choice of characters is essentially unlimited. Only one character is generated at a time. Hence, any character may be positioned at any point on the screen.	At speeds higher than 20,000 characters per sec component limitations destroy the display usefulness.	Stromberg-Carlson Div. General Dynamics (Similar tube made by Machlett Laboratories).
Compositron	Can display several thousand letters per sec.	Characters are displayed in luminous form for photographing. Output device in data processing system.			Radio Corp. of America
Indicoder	Can present 12 characters (numerals zero through nine, plus signal and minus sign). Displays are 1 in. high, discernable at a distance of 20 ft.	Displays a limited number of characters, one character at a time. Converts binary-coded digital words directly into a visual numerical display.	Small size, rectangular face; can be stacked in any desired pattern. Several hundred tubes can be operated in parallel by a common set of high voltage power supplies. No intermediate amplifiers required.	Can present only 12 characters.	Stromberg-Carlson Div. General Dynamics
Typotron	Combines shaped beam technique of charactron tube and storage technique of Memotron (see below). Character height is ⅛ in. Writing speeds are as high as 25,000 characters per sec. Resolution is 200 to 240 lines. (See Figure 2.)	Can display alphanumeric information at any location on the tube face, retain it indefinitely and erase it at command.			Hughes Aircraft Co. (Similar tube made by Machlett Laboratories).
DIRECT VIEW STORAGE TUBES	**Developed to circumvent the unsatisfactory brightness characteristics of long persistence phosphors. Intelligence is deposited on a storage mesh by a "write gun" at relatively slow rates; a "flood gun" provides a continuous stream of low velocity electrons which excite the phosphor stream in the pattern of the charges deposited on the storage mesh.**				
RCA 6866	Available with selective erasure. Three to four halftones can be reproduced; resolution is 400 lines at center. (See Figure 3.)	Developed as a bright indicator for airborne search radar applications. No deterioration in brightness for a period of 10 sec, and a satisfactory display can be maintained for 60 sec after writing has ceased.			Radio Corp. of America
Iatron	Available in two all-magnetic forms, and in an all-electrostatic direct view tube. Electrostatic focusing reduces resolution by 25 percent.	Writing speed between 10,000 and 100,000 centimeters per sec.	Offers controllable persistence (from 1 millisec to several minutes) and at least four discernable levels of brightness for halftones.		Farnsworth Div., IT&T
Tonotron	Available in 3-in. and 5-in.; 10- and 20-in. tubes under development.	Writing speed is 300,000 in. per sec (large sizes are 150,000 and 25,000 in. per sec).			Hughes Aircraft Co.
Memotron	Available in 5-in. tube.	Writing speed is 200,000 in. per sec. Writing speed of 1,000,000 in. per sec possible with special circuitry.	Persistence may last for days.	Cannot display halftones. Image presented must be intentionally erased. Erasure time is from 50 to 200 millisec.	Hughes Aircraft Co.
Dumont K1878	Available in 10-in. tube. Halftones can be reproduced with six levels of output brightness. Resolution is 50 lines per in. minimum.	Writing speed is a minimum of 20,000 in. per sec at maximum beam current.	Minimum storage of 3 min; erase time is 200 to 500 millisec.		Dumont Laboratories

TYPE OF DISPLAY	KEY FEATURES	APPLICATIONS	ADVANTAGES	LIMITATIONS	SUPPLIER
SCAN CONVERSION TUBES	**Nonviewing CRT into which video information can be stored at one rate and by one scanning method and from which the stored video can be extracted at a different rate and by a different scanning method. Raw radar data, for example, can be inserted, stored, and extracted for display on a standard CRT at rates that circumvent the undesirable brightness and persistence characteristics of long persistence phosphors. The resulting display can be flicker-free, bright, and viewed under higher light levels than a standard radar display.**				
Intec Video Transformation Tube TMA-403X	Double ended tube with magnetic deflection and electrostatic focusing on the write gun and electrostatic focusing and deflection on the read gun. Costs about $2,600. (See Figure 4.)	The definition of 1,000 TV lines is derived. Storage is adjustable from 0.1 sec to 20 min plus. It is possible to read the output signal on the order of 150 to 20,000 scans before erasure of the written information. The signal-to-noise ratio is 30 to 1.	Does not require RF modulation to sort the write and read signal. The tube is capable of halftone rendition. The tube shows 8 to 10 steps of gray in written information.		Intercontinental Electronics Corp.
Graphechon	Double ended, nonviewing, electrostatic charge storage tube. Costs about $1,100.	Used with scan conversion equipment, writing and reading can be conducted at the same time.	Can supply as many as 6,000 copies of stored information with a signal-to-noise ratio of 10 to 1.	Can produce only crude halftones. Requires some method of separating reading and writing signals, usually rf modulation or time-sharing.	Radio Corp. of America
Radechon	Single ended, nonviewing barrier-grid charges storage tube. (See Figure 5.)	Can store information received in analog or digital form.	Storage time is controllable from microsec to minutes. Information can be read out a number of times.	Must be time-shared for reading and writing.	Radio Corp. of America (Similar tube made by Farnsworth Div., IT&T).
Day Tube	Double ended storage tube. Uses three guns, electrostatic write and erase guns, and a magnetic read gun.		Storage time is several minutes.	Is still developmental.	General Electric Co.
Recording storage tube	Nonviewing device.	For scan conversion, indefinite image storage, slowed down video. Resolution is about 400 lines at 50 percent modulation level.	Signal can be stored for hours. Single image can be read out 20,000 to 30,000 times.	Time must be shared among four modes.	Raytheon
COLOR TUBES	**Can be programmed to display different variations at the same time. Major differences between tubes below stem from their means of obtaining color: stimulating different colors with separate guns or masking the phosphors.**				
Chromatron	Two- and three-color tubes available. Phosphors are laid down in thin parallel strips of alternating colors. Two sets of grids direct electrons to the proper color. (See Figure 6.)		Brighter and more efficient than shadow mask color tube (below). No convergence or misregistration problems. Not affected by the earth's magnetic field. Uses essentially same deflection voltages as standard CRT's.	Requires elaborate power supply.	Litton Industries
Shadow mask tube	Uses three guns spaced 120 deg apart and view plate on which are deposited three phosphor dots of different colors (red, green, and blue) in a triangle. Shadow masks are placed between gun and dots so that each gun can hit only one color dot.			Sensitive to slight variations in the earth's magnetic field. Protection must be provided against X-radiation. Brightness is limited. Color purity is hard to obtain.	Radio Corp. of America
Color Storage Tube	Combines features of Tonotron with shadow mask tube.	Can write at speeds up to 300,000 in. per sec.	Capable of halftone presentation. Resolution is 30 to 35 lines per in.	Display area limited (doubtful if 20-in. tube can be built). Still in development stage.	Hughes Aircraft Co.
Prismachrome (Gear Tube)	Three colored phosphors are geometrically oriented so that each gun illuminates only the desired phosphor.		Extremely rugged, cannot lose its registration alignment due to shock or vibration. High level of brightness is obtainable.	Tube is bulky for its screen size. Delivery time could be as long as 24 months.	Hoffman Electronics Corp.
Penetron	Color CRT with thin color phosphors deposited in layers on the tube face. The tube has one electron gun; color selection is achieved by varying the accelerating potentials. Difference for successive layers is on the order of 3 to 4 kv.	May be able to pass from one primary color through all the intermediate hues to the next primary color by appropriately adjusting the accelerating voltage.	Simpler and more rugged than shadow mask tube or Chromatron.	Only two color tubes have been built. Still in development stage.	General Electric Co.

Apple Tube	Color TV system using a beam indexing tube. Three primary color phosphors are deposited in narrow vertical strips on the tube face with an additional strip used for locating the writing beam. An electron gun generates two beams, one for writing and one for developing an indexing signal. As the two beams scan horizontally, the indexing beam generates a signal which synchronizes the intensification of the writing beam with the dot-sequential type of color signals.	Compatible color TV system.	Said to be more efficient than shadow tube and has no convergence problem because it does not use masks or grids.	Requires many circuit adjustments.	Philco Corp.
SPECIAL TUBES	**Radically different developments using cathode ray tube techniques that do not fit into any of the above groups. Advantages include brighter, sharper focusing in smaller space; high resolution; sharp display.**				
Skiatron	A dark trace tube; therefore coating absorbs light when bombarded with electrons.	Available with a refractive optical projection system that can throw a 10-ft diameter picture. Writing speed is sufficient for producing raw radar data. Resolution of projected display is 1,100 lines.	Projected displays are clear and sharp. Although ambient lighting can deteriorate projected display, local illumination for reading and writing will not affect the display if rays are prevented from striking the screen.	Requires time to build up to full contrast and time to decay after excitation is removed. Tube may be erased in 2 sec, but an additional 5 sec must elapse before rewriting can take place. To date limited to black trace on a bright background.	Skiatron Electronics and Television Corp.
Aiken Tube	Flat cathode ray tube. (See Figure 7.)	Linearity accuracy is 5 percent. Resolution is as high as 400 lines. Modifications under development: a) Two-color Aiken tube — glass plate with different colored phosphors is inserted between face plate and back plate of a standard Aiken tube. Uses a separate electron gun for each color. b) Three dimensional Aiken tube. Cube-shaped tube contains horizontal glass layers, each coated with a transparent phosphor. Each layer has an electronic gun. No goggles or viewing equipment required but third dimension presentation is discrete rather than continuous. c) Flat polar-coordinate CRT. d) Charactron flat tube — normal electron gun is replaced by Charactron components.	Three times the brightness of a conventional CRT, and 20 times the focusing power. 21-in. tube requires only 20 percent of power needed by conventional CRT. Potentially can be built in large sizes, up to 5 by 5 ft.	Delivery of 20-in. tube is 6 months. Large tubes have not actually been built.	Kaiser Aircraft and Electronics Corp.
Light Valve Tube	Scanning electron beam deposits charges on a special semiconductor screen which changes from opaque to transparent in accordance with pattern of stored charges. A lamp behind the screen shines through the pattern projecting it like the light of a slide. (See Figure 8.)		Bright display because of separation of projection light source and pattern generating functions.	Requires an additional year of development work for production.	Resdel Engineering Corp.
Large Cathode Ray Tube (30-in.)	Will operate with 30,000 volts accelerating voltage, magnetic deflection.	Tube has a curved face but is equipped with a plotting overlay to reduce parallax. Being built as a plan position indicator display.	Large display tube. Potentially high resolution, up to 1,000 lines.	High cost: $30,000. High voltage is hazard for operator. Brightness cannot compare to optical projection systems.	Polarad Electronics Corp.
Moving Target Indicator INTEC TCM-13X	Barrier-grid storage tube. A high definition triode gun with simultaneous read and write. Electrostatic focus and deflection; 15 shades of gray. Resolution of 400 TV lines is derived as measured by orthogonal write and read technique and with a 50 percent output signal modulation.	In moving target indicator techniques the tube provides an elimination ratio of 20.	Speed velocity of 0.6 mm per microsec. Signals can be added and integrated.		Intercontinental Electronics Corp.
INTEC TCM-154	Barrier-grid storage tube. A high definition triode gun with electrostatic focus and deflection and astigmatism correction lens. Definition: at 50 percent modulated output signal, the tube has about 700 TV lines.	Originally developed for electron switching in telephone circuits.	Erasure with television or similar-type raster; signals are stored and then read at a later time.		Intercontinental Electronics Corp.

Nonideal Diodes and Practical Function Generators

THE GIST: The basic circuits for electronic function generation using diodes were described in an earlier article ("How Diodes Generate Functions", March 1959, pp. 109-115) which considered the diodes as having ideal characteristics. Author Galli now goes on to discuss the effects of the nonideal characteristics of real diodes on function generators and concludes with a description of the most important universal diode function generators available commercially.

E. J. GALLI, Sperry Gyroscope Co.
Now with IBM Corp.

Figure 1 illustrates the current-voltage characteristic of an *ideal* diode—which is a perfect voltage sensitive switch—and two types of practical diodes. The resistance of the ideal diode is infinite when the potential of the anode is less than that of the cathode, and it is zero when the anode to cathode voltage is zero. Actual diodes have characteristics that only approach the ideal one indicated. The characteristics of a 6AL5 thermionic diode and of a Sperry Rand SD-20 silicon junction diode show that actual diodes do not have zero forward resistance. There is a transition region near the origin in which the conduction level varies smoothly from a high reverse resistance to a very low forward resistance. Outside of this transition region typical ratios of forward to backward conductance are on the order of 10^7 to 10^9 for thermionic and silicon junction diodes and 10^3 to 10^5 for germanium and silicon point-contact diodes. Due to the relatively low forward to backward conductance ratio of germanium and silicon point-contact diodes, these types are seldom used in function generators.

Thermionic diodes display a residual forward current at zero voltage due to the initial velocities of the emitted electrons. Note the zero offset current of the 6AL5 characteristic of Figure 1. This effect, plus that due to contact potential, results in an offset voltage at zero current which varies with cathode life (tube aging) and cathode temperature (heater voltage). A 10 percent change in heater voltage causes approximately the same percentage change in the offset voltage. Heater voltage regulation and preaging of diodes tend to stabilize this effect.

Silicon junction diodes develop no current at zero voltage (the characteristic passes exactly through the origin) but require several tenths of a volt before

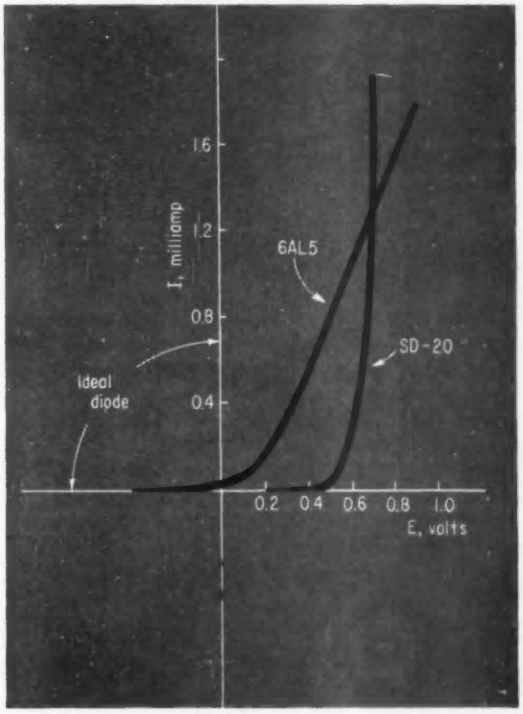

FIG. 1. Current voltage characteristics of ideal and real diodes.

appreciable conduction begins. This is caused by the relatively high energy level of silicon, which results in a region of extremely low forward conduction extending out to about 0.5 volts. Although this effect is relatively stable with regard to silicon junction diode life, it varies with ambient temperature at the rate of a few millivolts per deg F, resulting in temperature dependence errors of the same order of magnitude as experienced with relatively good passive components.

Diode nonidealities

In most cases, since the resistance and voltage levels used result in diode conduction currents ranging between 0.10 and several milliamperes, the dynamic diode resistance at these current levels will be small compared to the resistance in series with it and may usually be ignored. This is especially true with silicon junction diodes, since they have much lower dynamic resistance than thermionic diodes.

Due to the offset potential of the diodes, the actual function breakpoints in a practical function generator will differ slightly from the biasing voltages applied to the diodes. With silicon junction diodes, the contact potential acts effectively as an additional source of bias voltage of the same polarity, so that this effect may be taken into account by assuming that the effective bias voltage will be the sum of the actual bias plus the contact potential. With thermionic diodes, the residual current developed by thermal electron velocities causes conduction to begin when the plate to cathode potential is still slightly negative. The effect of this offset potential may be included by assuming that it acts as an additional source of bias voltage of the opposite polarity. In this case the effective bias will be the difference between the actual bias and the offset potential.

The reverse current of silicon junction diodes may have a small effect on diode generator performance, depending on the magnitude of the reverse current, the impedance levels of the circuitry, and the number of diode channels used. Low impedance levels tend to reduce the effects of reverse leakage. As techniques of silicon diode manufacture are further refined, diodes with negligible leakage currents and smaller temperature dependence should become available. At the present state of the art, the better silicon junction diodes have leakage resistances (approximately the nonlinear reverse characteristic by a best fit straight line) on the order of 1,000 to 5,000 megohms at normal room temperatures. It has been the author's experience that leakage resistance of this order of magnitude has a negligible effect on diode function generator accuracy, even for a 30-diode channel unit.

Silicon junction vs thermionic diodes

Several advantages are offered by the use of silicon junction diodes rather than thermionic diodes, provided ambient temperature variations are reasonable. The extremely small size of semiconductor diodes and the fact that no filament power is necessary are two of the major advantages. Diode function generators may be simplified in construction by the elimination of heater connections and tube sockets. Space requirements are correspondingly reduced.

Another major advantage is the better stability of the silicon junction diode over the thermionic type. To obtain optimum stability, diode function generators using thermionic diodes require regulated filament power supplies because heater voltage variations affect the offset potential. Furthermore, this effect varies as the diode ages. Thermionic diodes are usually preaged before they are used in diode function generators to avoid the fairly large change in offset potential occurring during the first 100 hours of operation. Although the rate of change diminishes after this initial period, change continues with cathode life.

Silicon junction diodes, on the other hand, do not have an aging problem, since the contact potential is a function of ambient temperature only. For average temperature variations the stability of the contact potential is very good, varying at the rate of a few millivolts per deg F. However, for operations over wide temperature ranges the thermionic diode is more suitable.

Practical diode function generators

The basic circuitry and general features of several commercially available universal diode function generators show how these facts modify only slightly in practical arrangements the basic circuits described previously (Reference).

The Beckman "Ease", Boeing "Beac", Donner, and Electronic Associates diode function generators all use the basic design shown in Figure 2 for one channel only. The simple grounded divider biasing method of Figure 7 (Reference) is employed here. The output is taken across the diagonal of the bridge network by the two summing amplifiers. A pair of diodes shares each set of bridge resistors. This versatile arrangement permits four-quadrant operation without switching and minimizes the effects of temperature variation. The Boeing, Donner, and Electronic Associates units use thermionic diodes, while the Beckman generator uses silicon junction diodes.

The basic design of the Goodyear diode function generator (no longer available), Figure 3, uses a series diode network in each parallel input channel, with biasing techniques of Figure 10 of the Reference using a voltage divider and summing network ahead of the diode. With this circuit the breakpoints of each diode pair are staggered so that, provided not too great a difference in break points exists, the net contribution of any diode pair to subsequent line segment slopes will be zero. This arrangement allows each slope segment of the function to be sub-

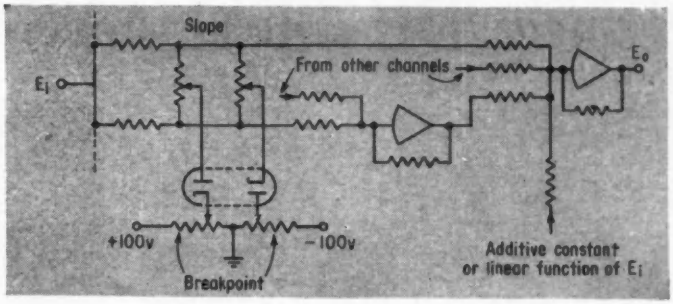

FIG. 2.
Basic diode function generator circuit used by Beckman, Boeing, Donner, and Electronic Associates.

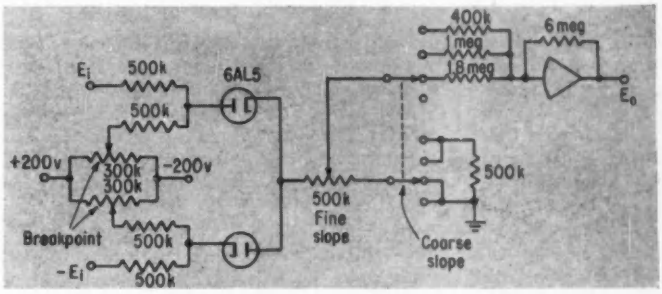

FIG. 3.
Diode function generator circuit used by Goodyear.

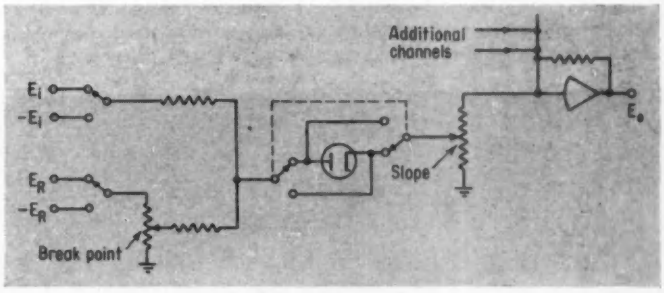

FIG. 4.
Diode function generator circuit used by Reeves.

ject to the drifts of only one diode-pair channel. The function slope depends on the characteristics of only one diode network at points other than the breakpoints, at which the effects of two diode networks are apparent.

Evidently the effects of breakpoint changes caused by diode and resistor drift may accumulate with this arrangement. However, a slope change in any one of the diode-pair channels will not affect the rest of the function slopes, and therefore low function drift results. Since twice the usual number of diodes are used with this technique, the calibration procedure is necessarily more elaborate and time consuming. A Goodyear DFG unit consists of five of these diode-pair channels.

The Reeves diode function generator, Figure 4, is similar to the Goodyear design, but does not use diodes in pairs. The contribution to the output of any one of the eight diode channels may be selected to appear in any one of the four quadrants by the quadrant switch used with each diode channel. Thermionic diodes are used in this design. Ten-turn helical potentiometers provide the breakpoint and slope adjustments.

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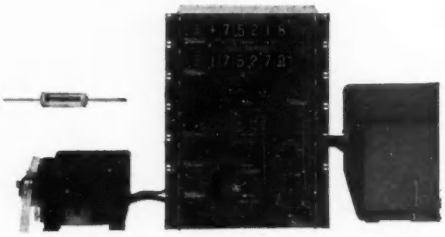
Low cost, versatile DIGITAL SYSTEMS

for automatic testing of transistors resistors diodes and capacitors



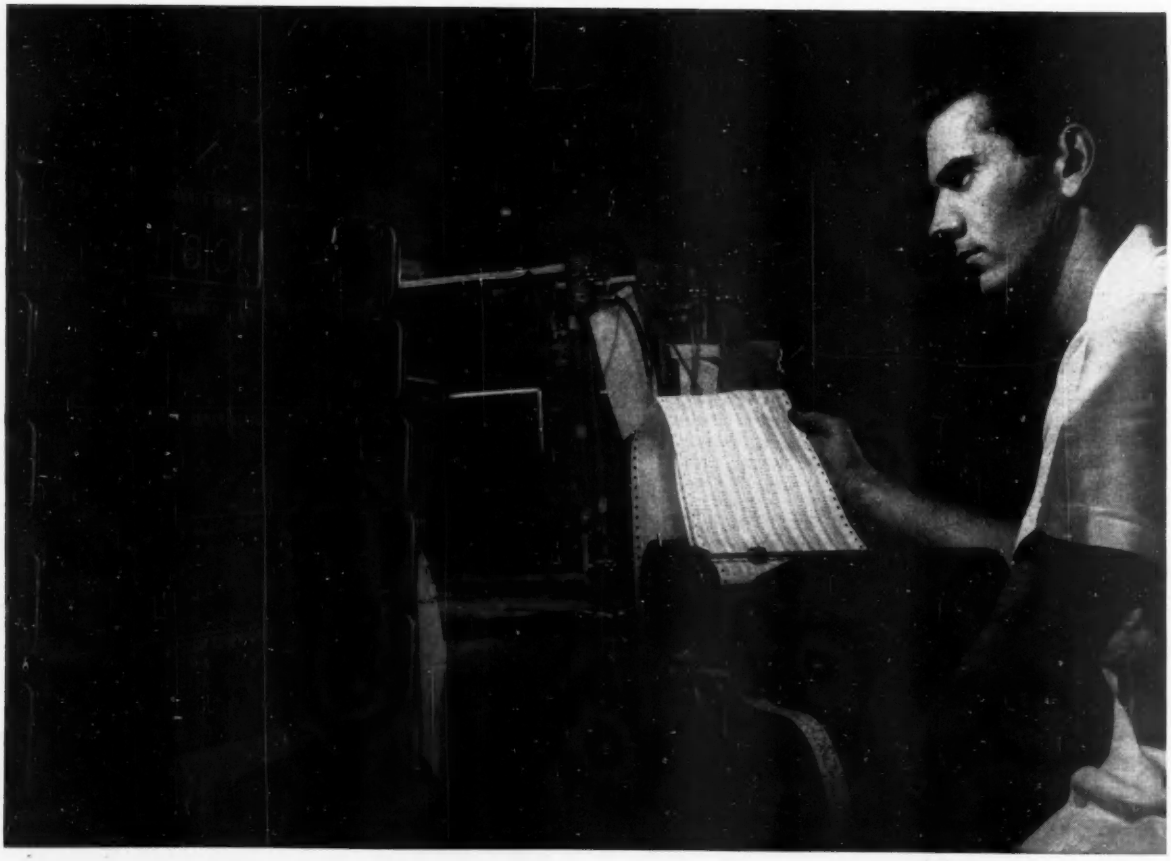
Small E-I automatic digital systems provide many advantages. First, they cost less. This is primarily the result of large-quantity manufacture of modules which make up the E-I system. Cost is almost a linear function of performance capabilities desired in the system.

Second, they are exceptionally versatile. The E-I system can be expanded simply by adding appropriate modules. Typical systems presently in use measure resistance, capacitance, DC and AC voltages, DC/DC ratios, AC/DC ratios, AC/AC ratios and combinations of these. Measurements to four or five digits can be visually displayed and printed out at rates up to five readings per second. Operation can be semi- or totally automatic with go/no go comparison of values and programmed readout at periodic intervals. Scanners can be provided for scanning thousands of single and multi-wire input channels. In brief, the E-I system has an extensive scope of operating capability.

Third, E-I systems provide unmatched reliability. Where practicable, circuits are totally transistorized. The use of etched, plug-in circuit boards, and modular internal construction make maintenance checks and in-plant repairs easy.

Typical E-I system for evaluating components—includes 100 channel input signal scanner. Can digitize DC voltage, resistance, AC voltage and DC/DC voltage ratio analogs. Digital equivalents are recorded on strip printer for "quick look" data and on punch paper tape for additional data reduction by digital computer.

Lower cost, maximum versatility and greater reliability—if you want these advantages in your component test system, contact your nearest E-I representative. He can give you complete information or answer any specific questions you may have.



Electro Instruments, Inc.

3540 AERO COURT
SAN DIEGO 11, CALIF.

Transistor NOR Elements Program Welder

FRANS G. DAHLIN
The Budd Co.

The Budd Monautronic Welding Control for the first time makes possible spotwelds of consistent quality. It does this by accurately regulating the temperature at the point of welding, the single factor most affecting the properties of the resulting bond. Temperatures below a certain level result in "cold" welds and thus, smaller "nuggets" or bonds; excessively high temperatures cause "splitting" or loss of metal, again reducing weld strength. In the past, it was impossible to regulate weld temperature because of the great number of variables involved: line voltage, applied force, electrode wear, surface conditions of the metal to be joined, etc. Feedback control was not easily applied because weld temperature is extremely difficult to measure.

What made the Budd development possible is the discovery that weld temperature is directly related to the voltage drop between the welding electrodes. Voltage is relatively easy to measure and to regulate by a control loop. This voltage or "heat" control is one of the vital sections in the Monautronic system. The second main section is the programmer that controls the sequence of operations of the machine. The programmer is digital and all solid-state.

Heat control

As it is received from the electrodes, the input signal to the heat control, Figure 1, is not a continuous ac wave. Instead, because of the adjustable-cutoff action of the ignitrons used to control welding current, it is in the form of a series of portions of half waves. The input circuit consists of a mechanical chopper, which operates as a synchronous rectifier, plus a transformer that isolates and gives voltage gain. The resulting voltage is compared with the command signal in a dc operational amplifier, and any difference is integrated. The output of the integrator is fed to a network that converts the dc voltage to pulse form for firing the thyratrons.

The heart of the converter is a 120-cps sawtooth generator. The output of the integrating operational amplifier is resistively added to the sawtooth. Large values of integrator output plus the sawtooth turn on a transistor (connected in the common base mode) early in the sawtooth. Small values of integrator output plus the sawtooth cause "turn on" late in the sawtooth. Use of linear time bases is new to welding. It has advantages over phase-shifting circuits.

The common base connection of the transistor makes it a good zero-crossing detector. Differentiating gives pulses that, with gain, fire C3J thyratrons. Using the conventional welding circuit, these thyratrons fire 20 to 50 amps for microseconds into the ignitor anodes that allow the large ig-

FIG. 1. Block diagram of feedback control for welding temperature.

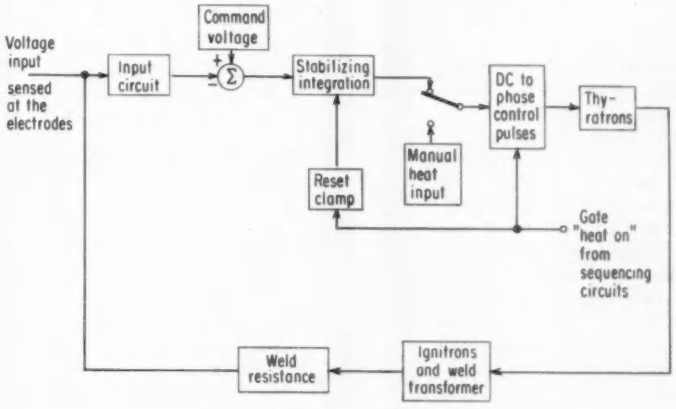
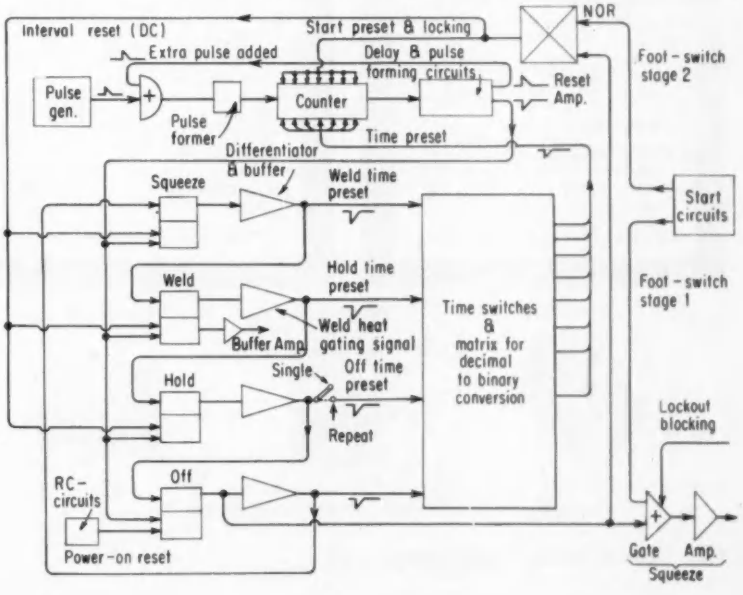


FIG. 2. Sequencing circuits. Various combinations of a standard NOR module are used to form the counter and multivibrator sections.



BASIC BUILDING BLOCKS FROM KEARFOTT

SIZE 11 SYNCHRONOUS MOTOR

Featuring pull out torque efficiency of 50% nominal with 3.4 watts input and 3 watts pull out power, this synchronous motor represents a major achievement in terms of performance for a unit of this extremely small size. Additional advantages made possible by Kearfott's unique design include resistance to environmental extremes, light weight construction and low unit cost. This motor and its variations are available in production quantities.

TYPICAL CHARACTERISTICS R172

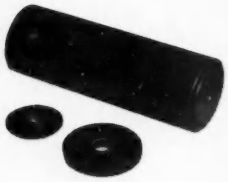
Excitation:	Phase 1	Phase 2
Voltage	40V	40V
Frequency	400 CPS	400 CPS
Power	2.3 Watts	2.3 Watts
Current	0.157 Amps	0.157 Amps

Performance:

Synchronous Speed	8000 RPM
Stall Torque	0.2 In. Oz.
Pull Out Torque	0.35 In. Oz.
Pull In Torque	0.15 In. Oz.

Write for complete data.

BASIC BUILDING BLOCKS FROM KEARFOTT



FERRITES

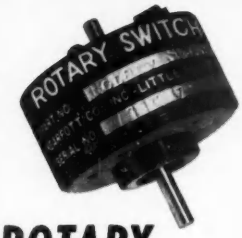
Kearfott's Solid State Physics Laboratory formulates, fires and machines permanent magnet ferrite materials of various compositions. Typical high-efficiency array utilizes Kearfott PM-3 ferrite material with specially designed pole pieces to produce a design both smaller and lighter than other arrays of equivalent magnetic field strength. Because magnets may be custom engineered to specific requirements, user is not restricted to stock magnet types, thereby providing greater latitude in parameters for focusing arrays. Pole pieces may also be provided according to specification, with the added assurance that, because of special Kearfott design techniques, B axial magnetic fields approximately 10% higher than those generally obtained in standard types may be produced.

TYPICAL CHARACTERISTICS

Peak Magnetic Field Strength	1200 gauss
Period	0.560 in.
Length	5.64 in.
Inside Diameter of Pole Pieces	0.400 in.
Outside Diameter	2.0 in.
Weight	3.2 pounds

Write for complete data.

BASIC BUILDING BLOCKS FROM KEARFOTT



ROTARY SWITCH

Kearfott's rotary switching devices for missile and aircraft systems are used to sequence or switch circuitry as a function of time or shaft position. Used in conjunction with sensitive relays or solid state switching techniques, high current loads can be handled. These switches consist primarily of shaft assembly and bearing mounted cylinder divided into conducting and non-conducting segments with continuous track for common input. Multiple conductor "broom" type brushes ride on each cylinder track while number of tracks and segmentation of each is function of the number of circuits and type of "on-off" sequencing required.

TYPICAL CHARACTERISTICS P1280-11A

Number of switching tracks: 2

Angular Segmentation (both referenced to 0° start):
Track 1 — Non-conducting about 0° + 50°
Track 2—Conducting 0° -180°
Non-conducting 180° -0°

Mechanical Accuracy of Segmentation:
±1° (better as required)

Starting and Running Torque:
0.1 oz.-in.

Current Capacity:
50 ma at 28V/Brush (suitable for any sensitive relay or solid state switching circuits)

Write for complete data.

Free Gyro

Vertical Gyro

Directional Gyro

Engineers: Kearfott offers challenging opportunities in advanced component and system development.

KEARFOTT DIVISION

GENERAL PRECISION INC.

LITTLE FALLS, NEW JERSEY

Midwest Office: 23 W. Calendar Ave., La Grange, Ill.
South Central Office: 6211 Denton Drive, Dallas, Texas
West Coast Office: 253 N. Vinedo Avenue, Pasadena, Calif.

nitrons to conduct.

At the end of each weld, the "heat on" signal from the sequencing circuits is removed, clamping down both the operational amplifier and the sawtooth oscillator. The ignitrons do not fire until the next weld is called for.

Programming

The logical circuitry of Figure 2 establishes the sequence of operations within each welding cycle. A feature of the design is the use of combinations of standard 60-cps transistor NOR modules to form the multivibrators that actuate the steps in the cycle and the binary coded decimal counter that provides the time base. Before each step, a counter with a 200-digit capacity is preset to the nines' complement of the number of cycles allotted and then counts to zero to start the next step.

When setting up for a particular type of weld, the operator programs the time for each step by adjusting selector switches on the control panel. When the start of an interval occurs, a pulse is directed through the 10-position switches on which the desired interval was set (in decimal form). The pulse then flows through a matrix of resistors that presets into the counter 199 less the desired interval in counts. Three hundred microseconds later another pulse is added into the counter. This extra pulse is required in a preset counter to perform the same basic function as the manual "carry" process encountered in subtraction.

The sequence of operations begins when the two-stage footswitch is depressed to its first position. This actuates the squeeze OR gate and causes the electrodes to close against the work. Next, the footswitch is pressed all the way down to open contacts in the reset line. With both input circuits now deenergized, the NOR circuitry delivers an output that ends reset. When reset, the SQUEEZE, WELD, and HOLD multivibrators are off; the OFF multivibrator is on; a count of 197 is on the counter. When reset ends, a 3-cycle time delay occurs before the start of the sequence. This delay isolates the sequencing circuits from the effects of any contact bounce in the control switch. When the counter overflows after three cycles, the OFF multivibrator resets.

The multivibrator output circuits are designed to deliver control pulses only when the multivibrators go from on to off. Thus, at this point the OFF unit triggers the time switches to prefill the counter with the complement of the squeeze time. At the same time it causes the SQUEEZE multivibrator to transfer. When the counter overflows, it generates a control pulse that resets the squeeze multivibrator.

Blocking Oscillator Linearizes Pneumatic/Electric Converter

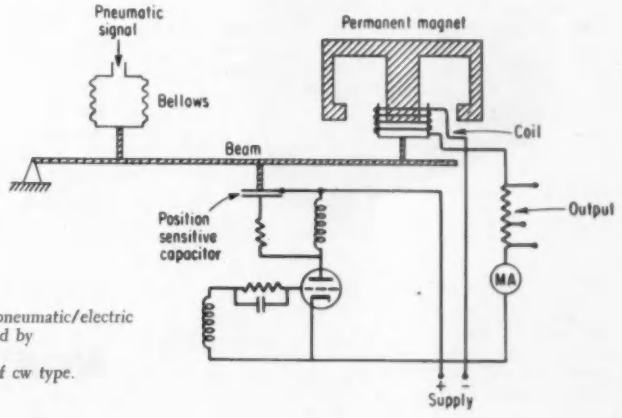
W. J. DONNELLY
Associated Electrical Industries
Harlow, England

Data logging applications where pneumatic control is used and signals require conversion before electrical measurement open up new fields for pneumatic/electric converters. Such converters need better than 0.5 percent output linearity, minimum sensitivity to supply voltage changes, and simplicity. The single tube blocking oscillator force-balance converter (see diagram) fills these requirements.

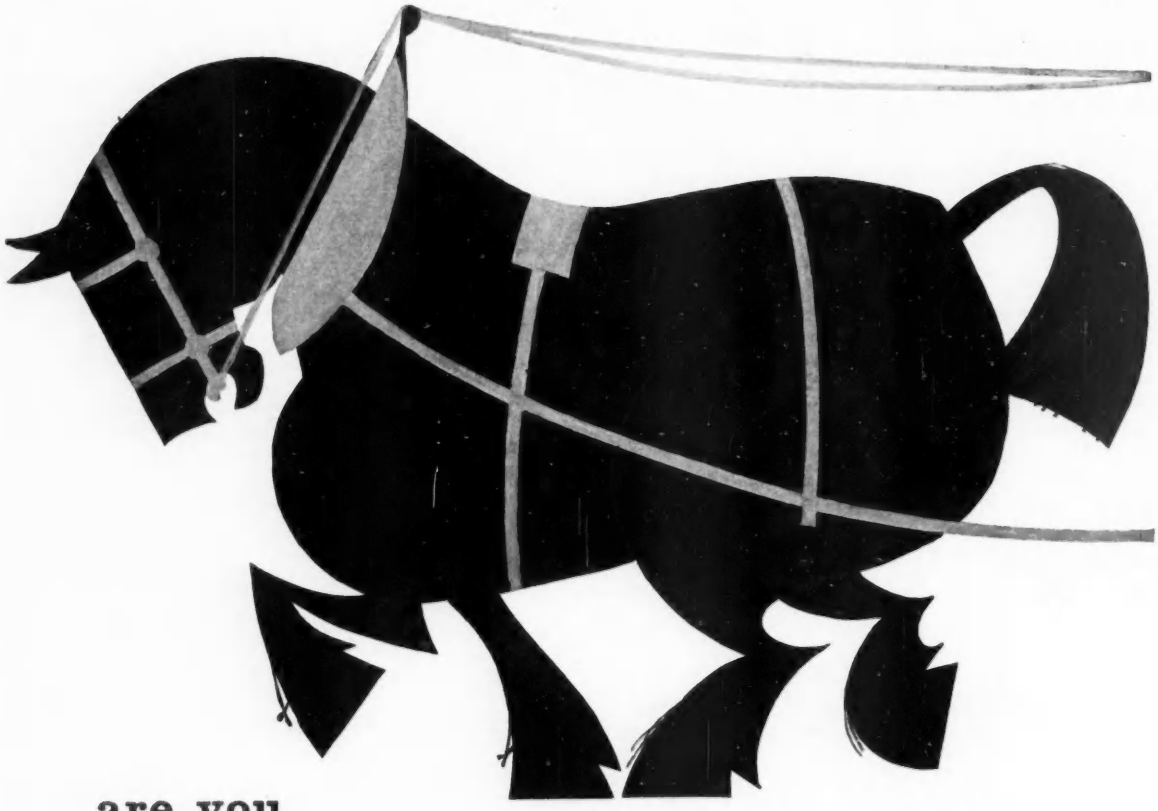
The diagram shows the basic principles of the system. The incoming 3-15 psi pneumatic signal acts via a bellows on a pivoted beam. The free end of the beam carries a feedback balancing coil operating between the poles of a permanent magnet. One plate of a parallel plate capacitor is also attached to the arm. The capacitor is connected in series with a resistor as a variable damping circuit across the anode coil of a 1-Mc blocking oscillator. A blocking oscillator has a larger plate current swing than the conventional cw type and thus provides higher feedback values to the force balance system to improve linearity. Movement of the beam (maximum travel, 0.004 in.) alters the plate current damping and hence the oscillation amplitude. The mean anode current therefore varies proportionally to the input pressure.

This current flows through the balancing coil on the beam, producing a beam moment equal and opposite to that of the input pneumatic signal. Resistors in series with the balancing coil current generate the electrical output proportional to the 3-15 psi pneumatic signal. Soldered link connections in the unit in one position give a 5- to 55-mv output and, in the other, 0.5 to 5.5 volts.

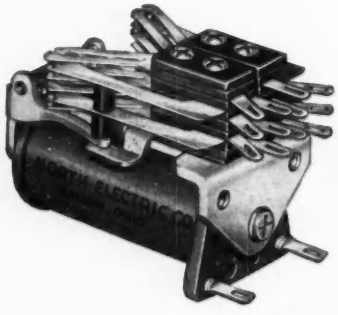
The blocking oscillator current range in the converter is from 0.5 ma to 20 ma. Linearity is improved to better than 0.3 percent by using a quarter of this 40 to 1 ratio to give a 1-10 ma dc output, and input supply variations of up to 10 percent produce less than 0.1 percent variation in output level. The system is substantially independent of ambient temperature, and the response time to a pneumatic input step change is 30 millisec.



Simple design of pneumatic/electric converter is realized by use of blocking oscillator instead of cw type.



are you using North Electric's Workhorse "E" relay?



Expanded production facilities and increased efficiency in manufacturing methods have enabled North Electric to step up production of "E" relays to provide prompt delivery (at a new low cost, too) to an ever-growing list of steady customers.

If you need a relay that incorporates the inherent proven dependability of a telephone-type relay with minimal spatial requirements, this "little workhorse" from North can be your answer!

GENERAL CHARACTERISTICS:

Light Weight (2½ ozs.)
Compact (Length 2¼"; Width 1⅛"; Height 1¾" max. with 10 springs in either pile-up)
Long Life (over 100 million operations)

SPECIFICATIONS:

Coil Voltages: Up to 250V DC
Contacts: Independent action twin contact springs
Contact Materials: Palladium, Gold, Platinum
Forms: A to C
Speed: 3 ms. minimum
Residual: Lock Screw (adjustable)—Fixed (nylon flap type)
Time Delay: Available for both operate and release
Coil: Single or Double wound
Mountings: 2 #6-32 Screws on ¾" spacing
Accessories: Dust Cover and Hold Down Bracket

ELECTRONETICS DIVISION

NORTH ELECTRIC COMPANY

612 S. Market St., Galion, Ohio

Servo-balanced Supply Tank Measures Nozzle Thrust

KENNETH HARRIS
PHILLIP DUNSTAN
Boeing Airplane Co.

A dual nozzle thrust balance instrument was designed to compare the thrust of an experimental nozzle with that of a standard nozzle at various air flow rates. The system automatically balances the thrust between the two nozzles and indicates the thrust difference digitally in pounds with a resolution of 0.01 lb.

The thrust balance tank, used as a weigh beam, is supported by two knife edges on a horizontal line normal to the longitudinal axis of the tank and equidistant from each end, Figure 1. Nozzles are located on opposite ends 48 in. from the axis of rotation, with their thrust axes vertical. The force producing the unbalance is the result of the difference in thrust of the two nozzles. A 40-lb weight moves through a 24-in. change of moment arm to correct for a 20-lb thrust difference. The distance the weight moves is measured by counting the number of turns of the lead screw. The lead screw is coupled to the counter by a synchro drive with a gear ratio to make the counter read directly in pounds of thrust difference.

Position sensing elements on each end of the tank produce a voltage when the tank is rotated away from the balance position, Figure 2. This voltage is amplified to energize the weight drive motor which moves the weight and balances the tank. Thin wall aluminum tubes normal to the longitudinal axis of the tank and on the center line of the knife edges supply the restoring torque and also provide the air supply to the nozzles.

The position sensors are variable permeance transducers excited by a 10-kc oscillator. The two transducers are connected as opposing legs in an inductive bridge circuit to double transducer sensitivity. Bridge output is demodulated for a polarity sensitive dc signal to the balancing servo.

In the servo the dc input is chopped to 60 cps, amplified, and used to trigger phase-sensitive thyratrons which supply power to the weight drive motor. The direction of travel of the weight is determined by the polarity of the dc input. The speed of the weight is proportional to the amplitude of the dc error signal: a sensitivity control permits adjustment of over-all gain; a slope control determines approach speed near the null.

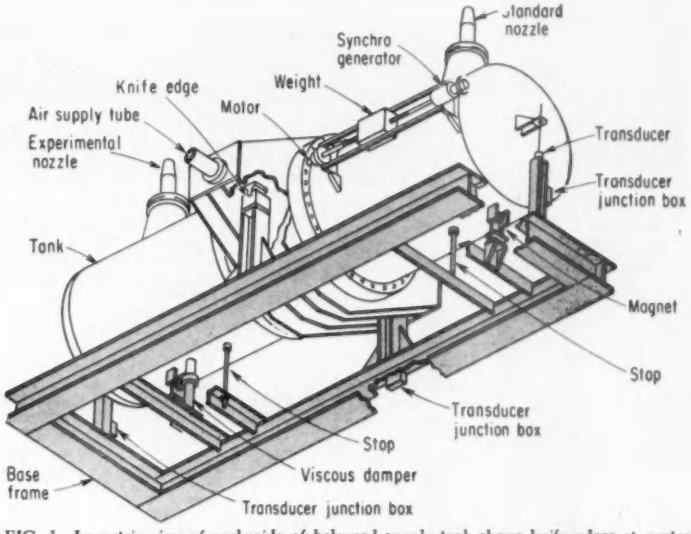


FIG. 1. Isometric view of underside of balanced supply tank shows knife edges at center with air supply tubes that provide restoring torque, as well as transducers, dampers, and lead magnets at either end. Shaded frame is stationary supporting structure. Nozzles are at top on either end.

Because of the inertia of the tank, the servo would cause the weight to overshoot the balanced position. To prevent continuous oscillation of the tank, electromagnets are installed on each end of the tank and connected across the motor through polarizing diodes to act as a lead circuit. An error signal energizes the proper magnet to start the tank moving at the same time that the weight begins to move and prevents overshoot.

Viscous damping is also provided at each end to reduce tank oscillation caused by turbulent air flow at high velocities. Damping is achieved by the relative motion of two 1.5-in. diam surfaces operating in Dow Corning 200 fluid of 50,000-C.S. viscosity.

Temperature effects are cancelled by connecting the tank position transducers in a bridge network. The output of the position sensing elements is zero at the balance position so the accuracy of the servo system is unaffected by supply voltage fluctuations. Likewise, nonlinearity of the transducers or amplifiers does not affect servo-system accuracy because the measurement of thrust difference is made at the point where the transducer output is zero. Also, since there is no torque applied to the air supply tubes at the balance position, they do not affect the accuracy of the system.

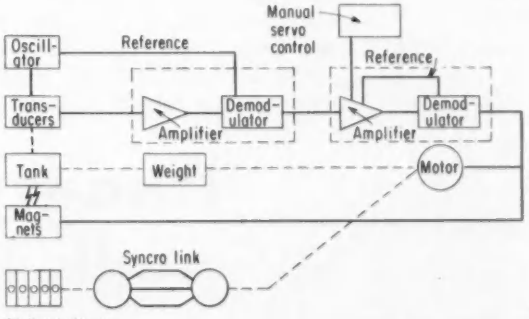


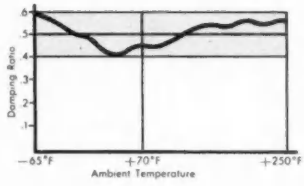
FIG. 2. Servo uses linear variable permeance transducers in bridge connection with transistorized amplifier - demodulator, thyratron power amplifier for dc balancing motor.

New Miniature Rate Gyro

Honeywell Miniature Rate Gyro
Type M-100
shown actual size

- Full Scale Range: To 400 degrees/sec.
- Linearity: Less than 0.1% of full scale to ½ range, less than 2% to full range
- Shock and Linear Acceleration: to 150G
- Size: 1" diameter, 2 19/32" long
- Threshold-Resolution: Less than 0.01 degrees/sec.
- Damping: 0.4 to 0.6 from −65°F to +250°F
- Vibration: 20 G to 2000 cps
- Weight: Less than 6.0 ounces

WARM-UP TIME
after motor run-up . . . ZERO!



When the chips are down and immediate action is a must, the new Honeywell Miniature Rate Gyros, Type M-100, are always ready. The typical damping of 0.6 at −65°F is obtained *without benefit of heat* from the spin motor, and is held virtually constant up to a temperature of +250°F. The gyro spin motor, requiring only 15 seconds run-up time, will operate on one (split), two, or three phase power, and is isolated from ground.

Other features of the Type M-100 include: unique quadrilever spring construction to produce greater shock and vibration capabilities than a comparable torsion bar gyro; elimination of one gimbal bearing for lower threshold; maintenance of preload throughout severe environmental conditions through exclusive spin motor construction.

Type M-100 is specifically designed for autopilot damping, radar antenna stabilization, and fire control applications. Its small size, high performance, and ruggedness suit it particularly for advanced military aircraft and guided missile applications. Write for Bulletin M-100 to Minneapolis-Honeywell, Boston Division, 40 Life Street, Boston 35, Mass.

75th YEAR
PIONEERING THE FUTURE

Honeywell

H HONEYWELL Military Products Group
SINCE 1885

Forward-Backward Counter For the Gray Code

GILBERT D. BEINHOCKER, Epsco, Inc.

The Gray unit distance code gets more common in control systems that use shaft-to-digital converters. Here is a way to count in the Gray code.

A unique circuit has been designed for counting in the Gray unit distance binary code that is considerably simpler than previous circuits. The new Gray code counter is made up of a normal binary counter, plus some AND and OR gates and complementing flip-flop register. Its operation rests upon the fact that any bit in the normal binary word that changes from zero to one should cause the corresponding Gray code bit to be inverted. (This rule can be seen from a study of the two codes, which are reproduced alongside the logic diagram.) No change, or a change from one to zero in a bit-column of the normal binary word causes no change in the Gray code counter.

Counter operation

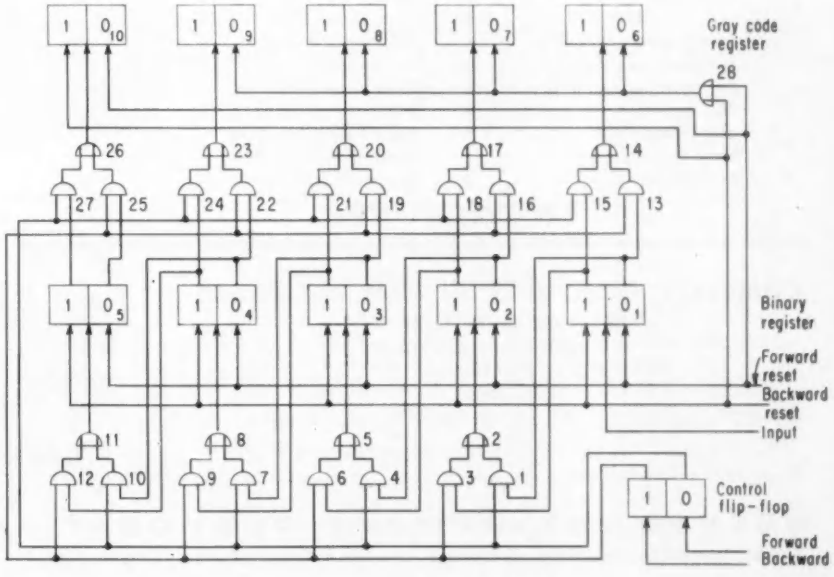
The new counter will count either forwards or backwards in the Gray code. To count forward it is necessary to reset all flip-flops in the two counting registers to the zero state by applying a pulse to the "forward reset" line and also to pulse the forward line of the control flip-flop at the lower right. The control flip-flop, in the zero state, puts a pulse-level voltage on gates 1, 4, 7, 10, 27, 24, 21, 18, and 15. Subsequent pulses applied to the line marked "Input" will then be counted in both registers:

1. The first pulse sets *FF*1 to the "one" state. The output (from the one state of *FF*1) will be blocked at gate 3 but allowed to pass gate 15 to set *FF*6 to one. Thus, the Gray counter contains 00001 after the first pulse.
2. The second pulse on the input line puts *FF*1 in the zero state, which via gate 1 sets *FF*2 to the one state, which output is blocked at gate 6 but allowed to pass at gate 18 to set *FF*7 to one. The Gray code counter now reads 00011, which is correct for the binary 00010.
3. The third pulse sets *FF*1 to one again, which is blocked at gate 3 and passed at 15 to set *FF*6 back to zero. The Gray counter now reads 00010, and the binary counter reads 00011, correct for a count of three.
4. The fourth pulse sets *FF*1 to zero, is blocked at gate 13, and passes gate 3 to set *FF*2 back to zero. *FF*2 output is blocked at 16, passes gate 4 to set *FF*3 to one. Output of *FF*3 is blocked at gate 9, passes gate 21 to set *FF*8 to one. Gray code counter now reads 00110, and binary counter 00100, correct for count of four.

The counting operation can continue as described for any number of stages although only five are shown in the diagram. By pulsing the control and reset lines marked "backward" the counter will start at its highest number representation (in this case 32, Gray 10000, binary 11111) and count down in both registers.

Decimal	Binary	Gray Code
0	00000	00000
1	00001	00001
2	00010	00011
3	00011	00010
4	00100	00110
5	00101	00111
6	00110	00101
7	00111	00100
8	01000	01100
9	01001	01101
10	01010	01111
11	01011	01110
12	01100	01010
13	01101	01011
14	01110	01001
15	01111	01000
16	10000	11000
17	10001	11001
18	10010	11011
19	10011	11010
20	10100	11110
21	10101	11111
22	10110	11101
23	10111	11100
24	11000	10100
25	11001	10101
26	11010	10111
27	11011	10110
28	11100	10010
29	11101	10011
30	11110	10001
31	11111	10000

Gray code counter has two registers, one for normal binary, one for Gray code; it will count forwards or backwards.



NEW PRODUCTS

ANALYSIS CONSOLE uses layman's language.

Photo right shows an operator seated before the new R-W Analysis Console, a unit designed to enable anyone to operate a digital computer without becoming familiar with the technical codes involved.

According to its manufacturers, the unit can be connected to any data processing system and, through the use of a simple keyboard arrangement, operators can control the computer and demand a display of data either in graphic or printed form on the console's video screen.

Typical applications include banking operations, stock market analysis, weather forecasting, inventory control, sales forecasting, or wherever nontechnical personnel use digital data systems.—Ramo-Wooldridge Div., Thompson Ramo Wooldridge, Inc., Los Angeles, Calif.

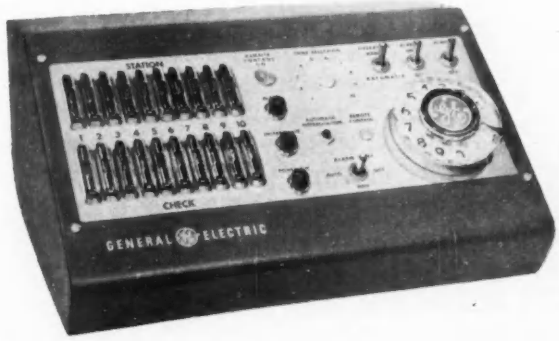
Circle No. 280 on reply card

NEW ENCODER offers 10-sec accuracy.

This Type RD-17 Digisyn, a new photoelectric shaft position encoder, provides unambiguous angular position data in 17-digit cyclic binary code with a plus or minus one digit accuracy. This is better than plus or minus 10 sec of arc. The 10-in., 26-lb unit consists of: binary coded glass disc, flash lamp to illuminate a radius of this disc, multielement photosensitive light detector, 17 transistorized amplifier channels, and all power supplies and control electronics.

Designed to operate from a 115-volt, 60- or 400-cycle source, it meets all applicable portions of MIL-E-4158B, features modular plug-in subassemblies, and contains a number of test points for checking circuit functions.—Wayne-George Corp., Boston, Mass.

Circle No. 281 on reply card



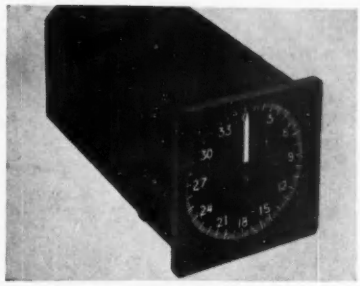
COMPACT CONTROL checks remote stations.

Designed primarily for utilities, pipelines, railroads, and other companies which monitor and control unattended remote stations from a central point, this new desk-mounting console allows an operator to check and control up to 10 functions at each point. Control signals, in the form of tones, may be transmitted via microwave, carrier current, or wire lines. Dialing system permits communication with as many as 100 different points. Two banks of 10 lights each indicate station and function being checked.—General Electric Co., Lynchburg, Va.

Circle No. 282 on reply card

NEW PRODUCTS

DATA HANDLING & DISPLAY



CONVERTS CODED INPUT

This new digital-to-analog converter indicator (T8613-14) consists of a relay matrix, a 2° analog-to-digital converter, and a 400-cycle, 115-volt motor. It receives pure binary information and provides analog output on a 360-deg dial graduated in 2-deg increments. A minor-arc sensing feature enables its analog movement to proceed through the shorter angular distance in reaching a null position. Internal wedge lighting illuminates both pointer and dial.—Kearfott Div., General Precision, Inc., Little Falls, N. J.

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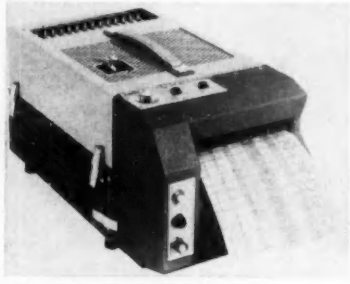
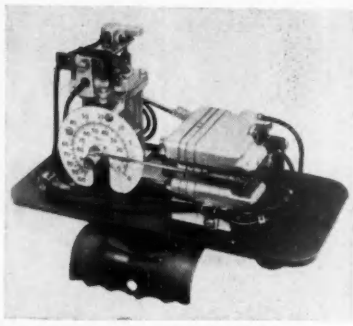


8-CHANNEL RECORDER

This new direct recording oscillograph, the 621 Standard, provides eight data traces on a 6-in. wide, light sensitive, recording paper. An optical magnet structure allows the instrument to record as many as 14 traces on the same size paper. Miniature light beam-type galvanometers provide excellent response from dc to 10,000 cps and permit information traces to overlap without interference. Record transport speeds range from 0.2 in. per min to 60 in. per sec.—Midwestern Instruments, Tulsa, Okla.

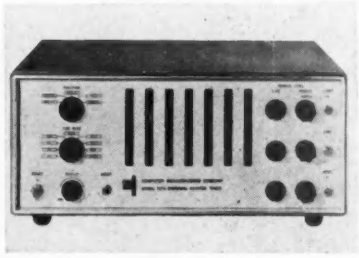
Circle No. 284 on reply card



FUNCTION GENERATOR

Constructed of time tested components, this compact unit provides a 3-15 psi pneumatic output that varies as a prescribed function of a 3-15 psi pneumatic input. It consists of a pneumatic servo and a transmitter. Feedback element of the servo is a precision cam, cut in accordance with the desired function. For linearizing flow signals (square root extraction), its accuracy is within 1 to 1¼ percent depending on output level. Unit weighs 13 lb and has an air consumption of 0.2 scfm. Price with square root cam is $200.—Taylor Instrument Cos., Rochester, N. Y.

Circle No. 285 on reply card



DC TO 10 MEGACYCLES

Shown is the Model 727A universal counter timer, one of three new transistorized dc to 10 Mc count, time, and frequency measuring instruments. Other units include the Model 707A frequency period meter and the Model 757A time interval meter. The 727A performs five basic functions, yet weighs only 27 lbs and requires about $\frac{1}{10}$ the power consumed by present day vacuum tube meters.—Computer Measurements Co., Sylmar, Calif.

Circle No. 286 on reply card

READS PUNCHED TAPE

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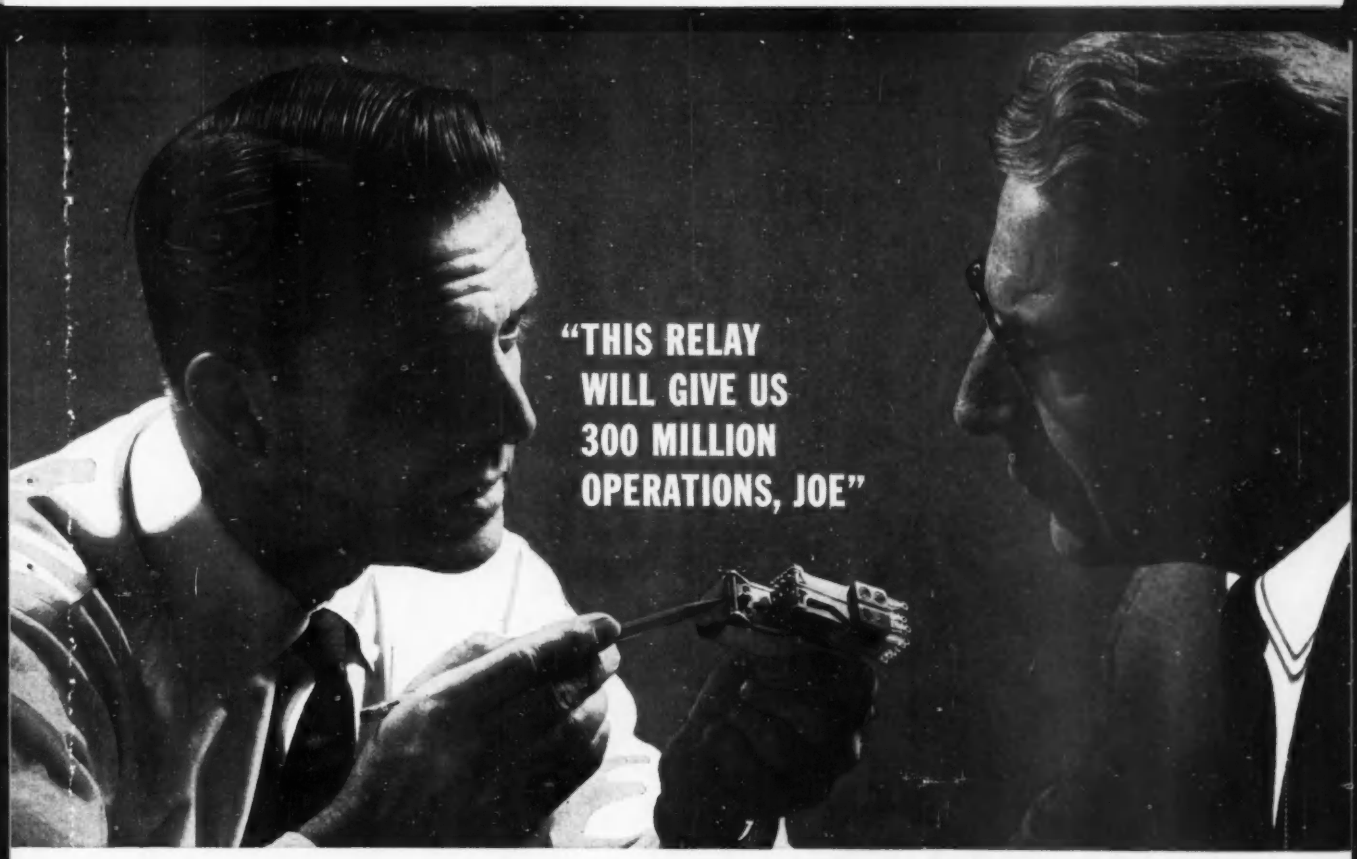
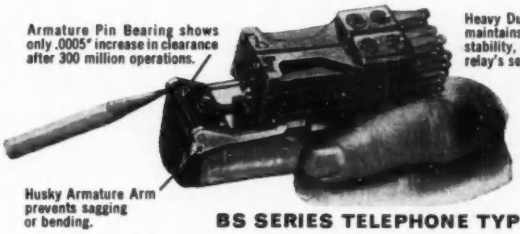


HERE'S WHY P&B TELEPHONE TYPE RELAYS GIVE YOU

reliable performance over long life



BS SERIES TELEPHONE TYPE

Measure the thickness of the BS series armature arm. You will find the cross section area is greater than ordinary relays of this type. Here is the kind of quality that spells dependability.

Observe that the stainless steel hinge pin runs the full width (not just half) of the armature, providing optimum bearing surface. This pin, operating in a stainless steel sleeve, shows only minimal wear during nearly a *third of a billion operations.*

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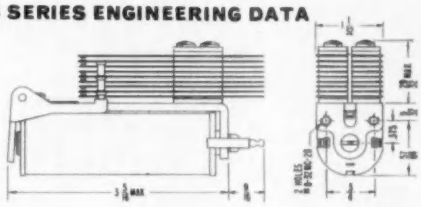
BS SERIES ENGINEERING DATA



GENERAL:
Breakdown Voltage: 1000 volts rms 60 cy. min. between all elements.
Ambient Temperature: −55° to +85° C. +125° C available on special order.
Weight: 9 to 16 ozs.
Terminals: Pierced solder lugs; Coil: One #16 AWG wire Contacts: Two #18 AWG wires
Enclosures: Dust covered or sealed

CONTACTS:
Arrangements: DC—up to 28 springs AC—up to 24 springs
Material: ⅛" dia. twin palladium. Up to ½" dia. single silver. Other materials on special order.
Load: 4 amps at 115 volts, 60 cycle resistive
Pressure: 15 grams minimum

COILS:
Resistance: 100,000 ohms maximum
Current: 10 amps maximum
Power: DC—50 Milliwatts per movable arm. Greater sensitivity on special order. AC—17.9 volt-amps.
Duty: Continuous
Treatment: Centrifugal impregnation
Voltages: DC—up to 300 volts with series resistor. AC—up to 250 volts, 60 cy.

MOUNTING: Two #8-32 tapped holes ¾" o.c. Other mountings on special order.

GS SERIES—Excellent sensitivity: 50 mw per movable arm minimum (DC). For applications requiring many switching elements in small space.

LS SERIES—Medium coil relay with short springs and light weight armature for fast action, reliability and long life.

TS SERIES—Short coil relay is available in AC and DC versions. Long life construction. Can be supplied (DC) with up to 20 springs (10 per stack).

P&B STANDARD RELAYS ARE AVAILABLE AT YOUR LOCAL ELECTRONIC PARTS DISTRIBUTOR

POTTER & BRUMFIELD

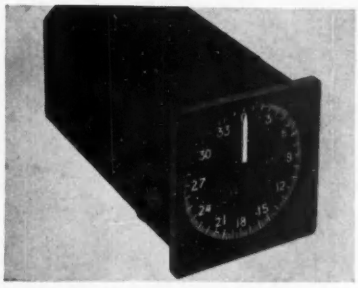
DIVISION OF AMERICAN MACHINE & FOUNDRY COMPANY, PRINCETON, INDIANA

IN CANADA: POTTER & BRUMFIELD CANADA LTD., GUELPH, ONTARIO

CIRCLE 121 ON READER SERVICE CARD

NEW PRODUCTS

DATA HANDLING & DISPLAY



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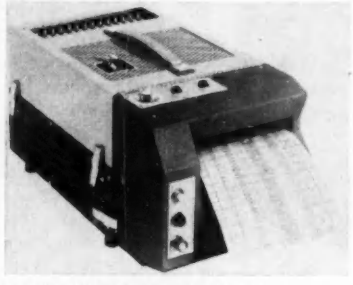

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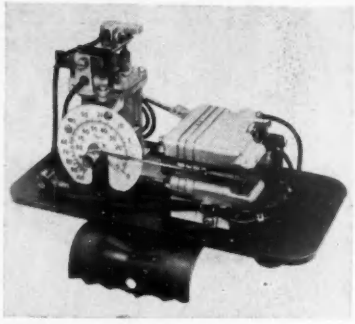

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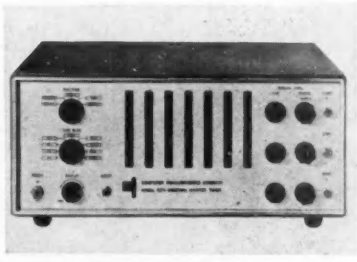

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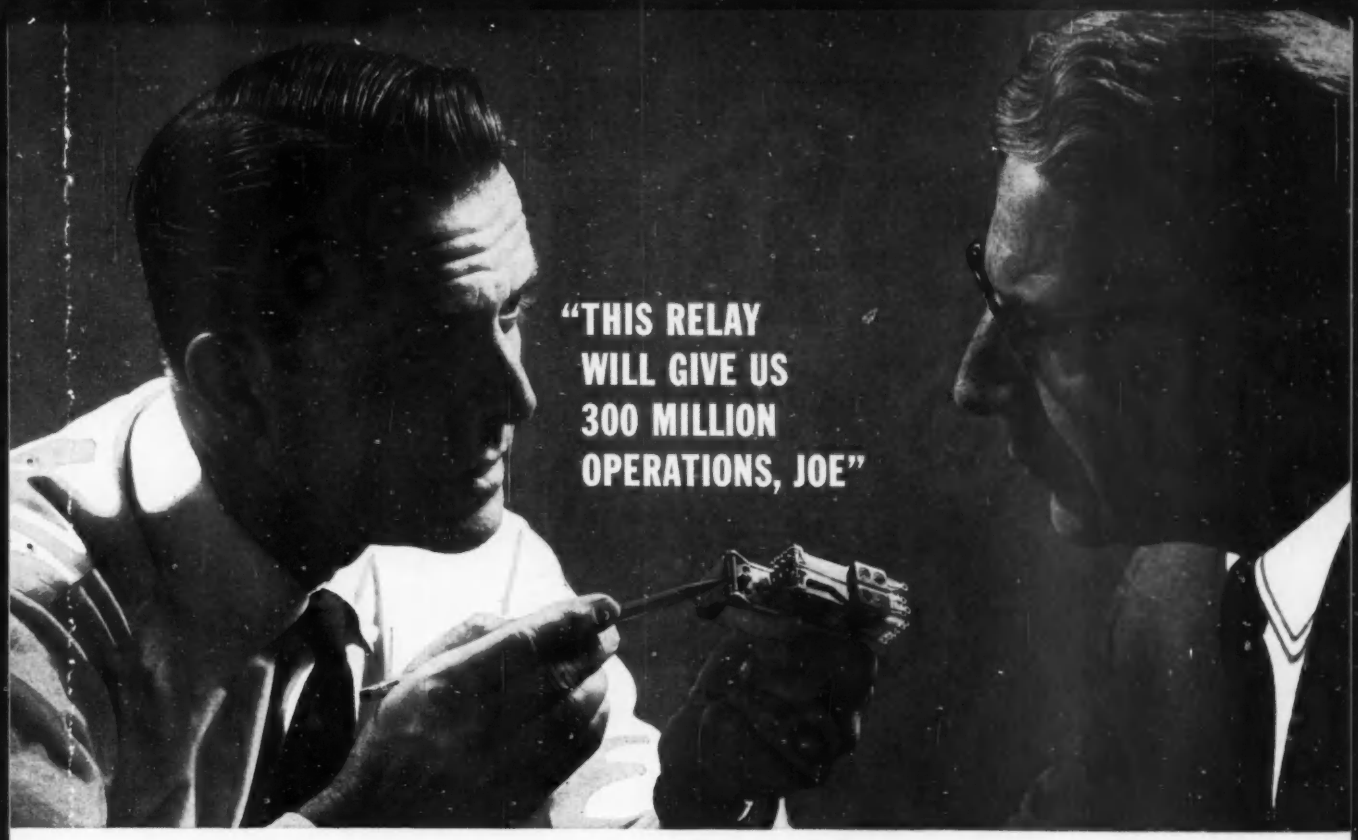

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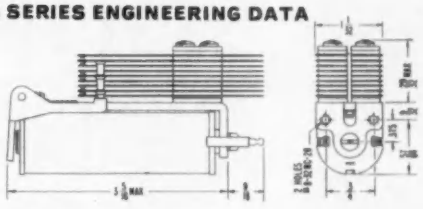

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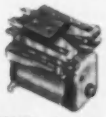

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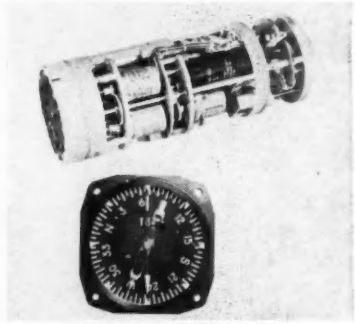
NEW PRODUCTS

1,000 characters per sec, it will stop within 0.5 msec after encountering a stop character (i.e., before the next character). Silicon photo diodes insure reliable, consistent reading levels. Unit fits a standard 19-in. rack and requires 180 watts at 115 volts., 60 cps. — Digitronics Corp., Albertson, N. Y.

Circle No. 287 on reply card



COMPUTING INDICATOR

Designated Type 9814-02, this compact airborne instrument combines the functions of a course indicator, azimuth indicator, and range indicator. It weights 50 percent less and has 60 percent less volume than the three units it replaces and eliminates two indicators from the instrument panel. Its single face presents compass information on a rotating compass card, distance information on a 3-digit counter, and relative Tacan bearing information on a double bar pointer. An auxiliary single bar pointer is also provided.—John Oster Mfg. Co., Racine, Wis.

Circle No. 288 on reply card

PLUS. . . .

(289) A completely revamped line of turbine **supervisory instrument systems,** now available from **General Electric Co.,** Schenectady, N. Y., requires about 65 percent less panel space. . . . (290)**Telemeter Magnetics, Inc.,** Los Angeles, Calif., has introduced a new magnetic core **memory stack,** designed to withstand the rigors of military applications. . . . (291) Data conversion from four binary inputs to a tape recording in the IBM 704 format can be performed by a new **all-transistor converter** manufactured by the **Electronic Engineering Co.** of Calif., Santa Ana, Calif.

Circle Nos. 289, 290, or 291 on reply card

NEW *system*...
NEW *capabilities*...

FOR COMPLETE ON-LINE DATA REDUCTION

Combining the RW-300 Digital Control Computer with its matched magnetic tape unit creates a powerful new system for on-line data reduction. For the first time, a single compact system can fulfill all data reduction requirements at the test site. The system will automatically scan measuring instruments, convert their readings to digital form, and store this data on magnetic tape at a maximum rate of 2,560 words per second. Generally, the RW-300 will also compute quick-look data and feedback control signals. Within minutes after a test is finished the system will automatically produce complete test data and results in meaningful form. For further information, call or write Mr. Raymond E. Jacobson, Director of Marketing, The Thompson-Ramo-Wooldridge Products Company, 202 North Canon Drive, Beverly Hills, California, BRadshaw 2-8892.

The **RW-300 DIGITAL CONTROL COMPUTER**

with the

NEW MAGNETIC TAPE UNIT

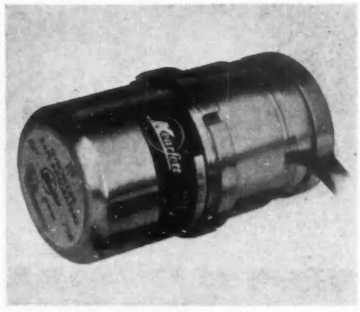
EXPEDITES TESTING
REDUCES COSTS

THE THOMPSON-RAMO-WOOLDRIDGE PRODUCTS COMPANY

a division of ***Thompson Ramo Wooldridge Inc.***

NEW PRODUCTS

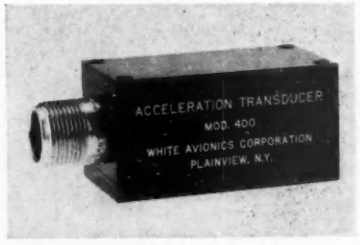
PRIMARY ELEMENTS & TRANSDUCERS



EXTREME ACCURACY

This M2514-02B miniature floated rate integrating gyro features an unusually large angular input capability and a permanent magnet torquer that provides a linearity within 0.02 percent at torquing rates up to 1,000 deg per hr. Its angular momentum is 250,000 gm-cm² per sec. These and other characteristics enable the unit to be used in place of a stable platform in certain systems. – Kearfott Div., General Precision, Inc., Little Falls, N. J.

Circle No. 292 on reply card



LIGHT-WEIGHT PICK UP

Suitable for control, telemetry, and guidance system applications, this potentiometric type accelerometer, the Model 400, features low static friction and infinite resolution. Response of its sensor is flat to 50 cps over an acceleration range of 0 to 10 g's. Unit measures 1⅛ in. square by 2¼ in. long, and weighs less than 5 oz.–White Avionics Corp., Plainview, N. Y.

Circle No. 293 on reply card

STANDARIZED PROBES

A brand new line of resistance-type temperature probes has been designed

HAGAN NEWSLETTER—FEBRUARY

Behind the panel

THE DAY THEY MISSED THE LUNCH WHISTLE

It wasn't planned that way--it was just that this group of engineers got so interested in the PowrMag story that they ignored the lunch whistle. Small wonder--because magnetic amplifiers are claiming top attention from instrument engineers today, and the way Hagan uses them makes them even more interesting. Here is a system that is almost an exact analog of a similar pneumatic system--easy to understand, easy to work with. All the advantages of solid state--no tubes--no transistors--and circuitry that is so simple that maintenance problems become a minor consideration. Passive networks, parts of the compact plug-in box, provide proportional band, reset and rate action. All parts are high-quality components, operated far below their ratings--result, high stability and long life. A unit will use no more than 2 or 3 watts, so heat is no problem. DC signals mean centralized control is possible at any distance, and outputs are compatible with data processors and computers. If you would like to hear more of the PowrMag story, give Hagan a call. (Details on request--Ask for Item L-1)

BOILER FOR SOUTH AMERICAN STEEL MILL FIRES FIVE FUELS--AUTOMATICALLY

Hagan systems, including combustion, 3-element feed water and furnace pressure controls, will be installed on a 53,000 KW station in South America. Two boilers, each producing 350,000 lb. steam/hr., at 900 psig and 900 FTT, will be fired with the following fuels, in the order given: coke breeze, blast furnace gas, coke oven gas, heavy fuel oil. Provisions have also been made to fire pulverized coal at a future date. Because of the number of fuels and the complicated firing procedure, a special set of interlocks have been incorporated into the control system. The boilers are designed to burn a preset rate of stoker-fed coke breeze, so this amount is deducted from the total fuel demand. When required, blast furnace gas is fired if pressure indicates it is available. As demand exceeds this combination, coke oven gas is fired, and so on, all automatically. Operating under typical steel mill load, the combustion control system is designed to follow load swings that may range as high as 60%, with peak intervals as low as two minutes and peak durations of thirty seconds.
(Details on request--Ask for Item L-2)

HAGAN CONDUCTIVITY METER SAFEGUARDS CRITICAL SOLIDS CONCENTRATIONS

Where the concentration of dissolved solids in a solution is critical, the Hagan Conductivity Recorder and Sampling Cell provides a continuous reliable measurement for a moderate investment. The Hagan Model H-0 may be utilized as a single instrument, or up to four different conductivity measurements may be recorded in a single instrument case. The recorder may be mounted up to 1000 feet from the point of measurement. For the determination of dissolved solids in steam, appropriate cooling coils, steam dryers and degassers are available. For feed water and condensate systems, where fluid temperatures do not exceed 140F, the conductivity cell may be used without cooling. Temperature compensation is automatic and continuous, and limit switches may be installed to activate alarms. This protects systems where cooling water leaks into the condensate may occur. (Details on request--Ask for Item L-3)

TOP PRESSURE CONTROL INCREASES BLAST FURNACE EFFICIENCY

Iron production in a blast furnace can be raised by increasing the weight of a gas per cubic foot within the furnace, bringing more oxygen in contact with the burden. Hagan Automatic Top Pressure Control accomplishes this without increasing gas velocity, thus avoiding raising of dust loading. A typical installation in an eastern steel mill made use of existing butterfly valves, one 30", the other 54". Since only the 30" valve had good regulating characteristics, the two valves are operated in parallel, providing adequate capacity for handling system gas as well as system bias. A blocking valve, operated by a limit switch on the charging bell, overcomes the momentary surge that would occur each time the bells were set. Since the installation of the Hagan system, iron production has increased, and furnace operation is smoother. (Details on request--Ask for Item L-4)

HAGAN CHEMICALS & CONTROLS, INC., Hagan Building, Room 711, Pittsburgh 30, Pa.

HAGAN DIVISIONS: CALGON CO. — HALL LABORATORIES — BRUNER CORP

NEW PRODUCTS

to minimize the number and kinds of parts required. New mounting, for example, permits variation in probe length or replacement of the resistance element without disturbing the fitting. Sensing elements of nickel-iron, platinum, and thermistor materials cover temperature ranges from minus 320 deg F to 1,000 deg F; outputs range from 0 to 5 volts.—Arnoux Corp., Los Angeles, Calif.

Circle No. 294 on reply card

DENSITY GAGES

Two new gages, the Models LR and LRV, use gamma radiation techniques to continuously, automatically, and accurately measure specific gravity, percent solids, or interface passage in 10- to 16-in. pipelines. Gages contain no moving parts and require no contact with the process fluid. Heavy shielding of the radioactive source permits general license distribution by the AEC to companies with no prior radioisotope experience. Extremely narrow spans and accuracies to within 1 percent of scale can be furnished.—The Ohmart Corp., Cincinnati, Ohio.

Circle No. 295 on reply card

(296) **Yarnall-Waring Co.,** Philadelphia, Pa., offers a line of **differential pressure transmitters** for the 0- to 400-in. range. . . . (297) The Series 5 **pendulum potentiometers,** developed by **Edcliff Instrument,** Monrovia, Calif., provide positive indication of pitch and roll attitude of nonaccelerating platforms. . . . (298) **Norden Div., United Aircraft Corp.,** Stamford, Conn., announces a new 6-in. BCD **shaft position encoder** accurate to one part in 1,000.

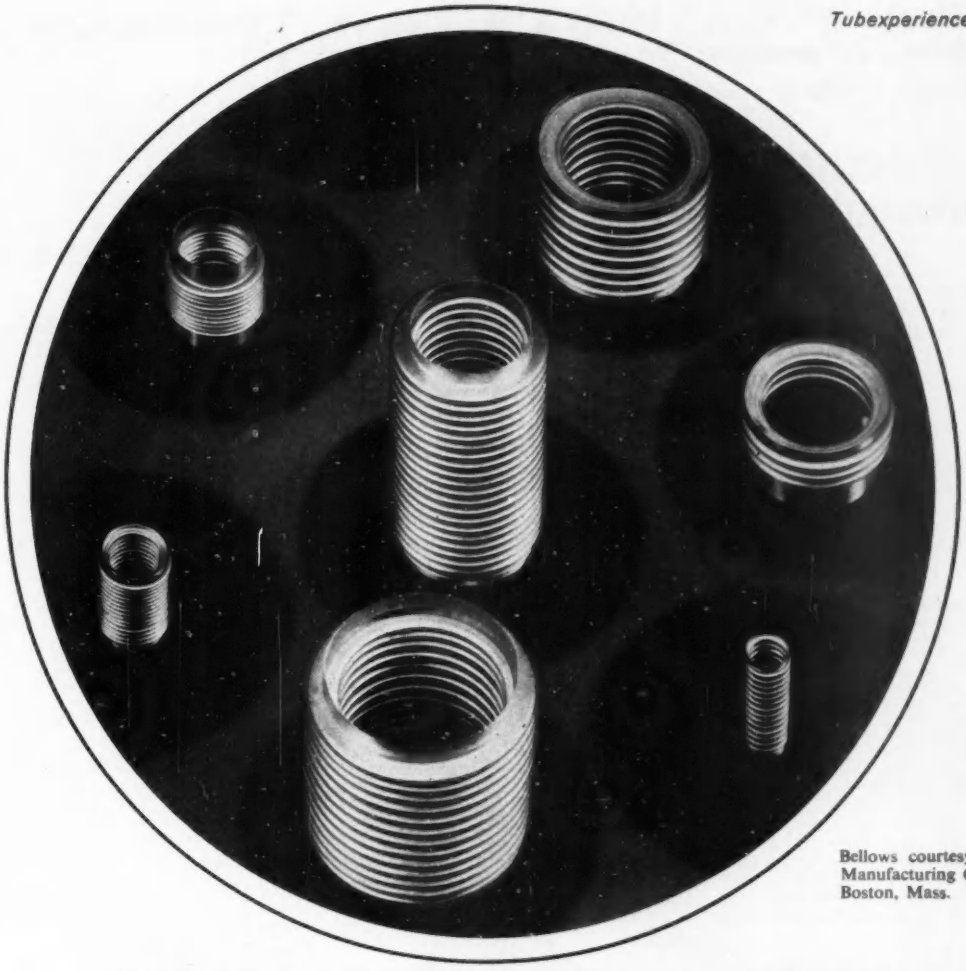
Circle Nos. 296, 297, or 298 on reply card

CONTROLLERS, SWITCHES & RELAYS

PYROMETER CONTROLLER

A new indicating pyrometer controller, the Type Z5, combines a millivoltmeter measuring system with a simplified vane-type control system. It operates an internal load relay directly, with-

Tubexperience in action



Bellows courtesy Clifford Manufacturing Company, Boston, Mass.

750,000 flexures without failure

—a common performance record for bellows formed from Superior Thin-Wall Tubing

Bellows, more sensitive than spirals and better adapted to accurate measurement of pressure and vacuum, or absolute pressure in the low and intermediate range, must withstand thousands of flexures without failure. The tubing from which they are made must be highly uniform in physical and mechanical properties and must have the invariably smooth surfaces that contribute so much to good fatigue life. It must be extremely ductile—forming pressures run as high as 5000 psi. Brazing operations used to fasten it to another assembly may subject it to temperatures up to 1800°F. It must have excellent corrosion resistant characteristics. And it must be free of carburization, dents and pickups that lead to premature fatigue failure of the bellows in service.

Thin-wall tubing of this quality—usually under .010 in. max. wall thickness and held to a tolerance spread of only one-thousandth inch—requires the skills and facilities of tubing specialists. Superior maintains production standards fully in keeping, employs special handling procedures, uses special controlled-atmosphere furnaces to provide the uniformly annealed tubing demanded. Superior tubing is produced in a wide range of analyses, in both Seamless and WELDRAWN® types, and to specified IDs, ODs and wall thicknesses.

Bellows tubing is just one of many types supplied by Superior. Available are more than 120 analyses, in a wide range of sizes, and meeting almost any requirement. For a good glimpse of the field covered by Superior, send for Bulletin 41. Superior Tube Company, 2026 Germantown Ave., Norristown, Pa.

Superior Tube

The big name in small tubing

NORRISTOWN, PA.

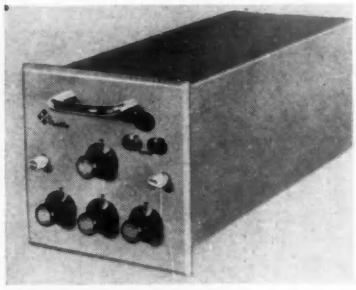
All analyses .010 in. to ⅝ in. OD—certain analyses in light walls up to 2½ in. OD

West Coast: Pacific Tube Company, Los Angeles, California • FIRST STEEL TUBE MILL IN THE WEST

NEW PRODUCTS

out tubes, transistors, or magnetic amplifiers. Control differential gap plus all drifts is less than 0.25 percent of scale for the full life of the instrument.–Atlantic Pyrometers, Inc., Hawthorne, N. J.

Circle No. 299 on reply card



SIMPLE COMPUTER

Built to receive electrical analog signals from transducers and perform any required computation, this compact magnetic controller is the key component in the new PowrMag solid-state analog computer control system. Unit features plug-in modules for any of the following functions: addition, subtraction, ratioing, integration, differentiation, or multiplication. Output signals may be transmitted to valve positioners, damper operators, saturable reactors, and other final control elements.–Hagan Chemical & Controls, Inc., Pittsburgh, Pa.

Circle No. 300 on reply card

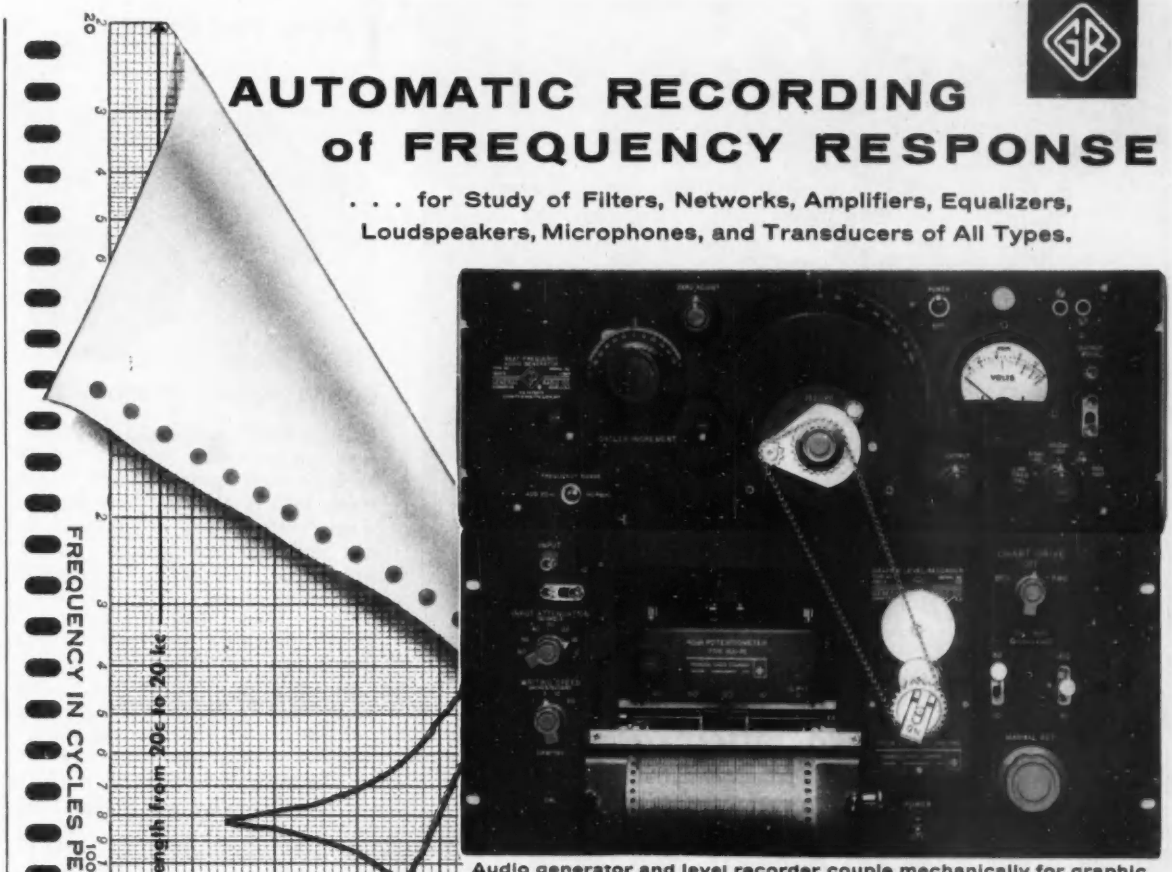
TIME-DELAY SWITCH

Shown is one of three new solid-state time delay switches featuring hermetically sealed components. Light, medium, and heavy duty types handle currents up to 10, 16, and 50 amps, respectively. Maximum power required is 50 ma and the standard operating voltages are 24-31 vdc. Black anodized aluminum case measures 1¼ in. in diameter by 2 in. long. Terminals include two ¼-28 NF lugs and one solder lug.–George Harmon Co., Northridge, Calif.

Circle No. 301 on reply card

AUTOMATIC RECORDING of FREQUENCY RESPONSE

. . . for Study of Filters, Networks, Amplifiers, Equalizers, Loudspeakers, Microphones, and Transducers of All Types.



Audio generator and level recorder couple mechanically for graphic recording in db on a truly logarithmic frequency scale.

PRICES: Type 1304-B Beat-Frequency Generator $625
Type 1521-A Graphic Level Recorder (with 40-db pot) $995
Type 1521-P10 Drive Unit ..... $ 72
Type 1521-P11 Link Unit ..... $ 18
Complete System $1710

Chart paper only $2.30 per 100-ft. roll

SYSTEM SPECIFICATIONS

Frequency Range: Generator, 20c to 20 kc on logarithmic scale, 20 kc to 40 kc. Recorder, traces rms level from 20c to 200 kc.

Generator Output: flat within ±0.25 db from 20c to 20 kc. Output is adjustable from 5 mv to 50v open-circuit. Harmonic distortion is less than 0.25% from 100c to 10 kc, 0.5% below 100c, 1% above 10 kc.

Recorder Sensitivity: 1 mv, maximum (corresponds to 0 db). Can be varied from 1 mv to 1v in 10 steps with input attenuator.

Recorder Range: 40-db full scale, with plug-in potentiometer supplied; 20-db and 80-db pots also available.

Pen Writing Speed: 20 in/sec maximum with 40-db Pot (200 db/sec) with less than 1-db overshoot. Slower speeds (1, 3, or 10 in/sec) selected by panel switch to provide mechanical filtering of rapidly fluctuating levels.

Paper Speeds: 2.5, 7.5, 25, and 75 in/min. Optional slow-speed motor available for speeds from 2.5 to 75 in/hr.

Recorder Accuracy: Static accuracy better than 0.4% of full scale. Fast servo system with low overshoot provides excellent dynamic accuracy.

Write For Complete Information

GENERAL RADIO COMPANY

Since 1915 — Manufacturers of Electronic Apparatus for Science and Industry

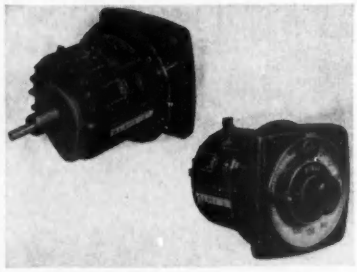
WEST CONCORD, MASSACHUSETTS

NEW YORK AREA: Tel. N. Y. WOrth 4-2722, N. J. WHitney 3-3140 **CHICAGO:** Tel. VIllage 8-9400
PHILADELPHIA: Tel. HAncock 4-7419 **WASHINGTON, D. C.:** Tel. JUniper 5-1088
SAN FRANCISCO: Tel. WHitecliff 8-8233 **LOS ANGELES 38:** Tel. HOllywood 9-6201
In CANADA, TORONTO: Tel. CHerry 6-2171

We introduced our first cathode-ray oscilloscope with a German-made tube in 1931, and in 1933 substituted a better tube manufactured by Westinghouse. We introduced the linear sweep circuit in 1932. That circuit is still used in today's scopes.

CIRCLE 129 ON READER SERVICE CARD

NEW PRODUCTS



COUNTS SHAFT TURNS

Dial on this new shaft-driven revolution counter carries two pointers: a knob-operated green pointer that shows total revolutions per cycle and a red pointer that moves toward zero and indicates cycle progress. Unit will handle shaft speeds up to 1,000 rpm and requires only 1¼ oz-in. torque. Heavy duty SPDT control contacts trip at a predetermined setting while clutch action permits automatic reset. Both ac and dc models are available with ranges from 12 to 240,000 revolutions.—Automatic Timing & Controls, Inc., King of Prussia, Pa.

Circle No. 302 on reply card

PLUS. . . .

(303) **Hydro-Aire Co.**, Burbank, Calif., offers a new series of ultra-miniature **time delay devices** with ranges from 0.05 to 180 sec. . . . (304) Two new "maintained-contact" **actuator types** broaden the variety of limit switches available from **Micro Switch Div. of Minneapolis-Honeywell Regulator Co.**, Freeport, Ill. . . . (305) A submiature adjustable **pressure switch,** introduced by **The Bristol Co.**, Waterbury, Conn., exceeds the requirements of MIL-E-005272B for performance up to 200 psi.

Circle Nos. 303, 304, or 305 on reply card

ACTUATORS & FINAL CONTROL ELEMENTS

AIR OPERATED VALVE

Designed for high pressure service, the Model 4888 remote control needle valve has a conventional needle-type stem coupled directly to a pneumati-

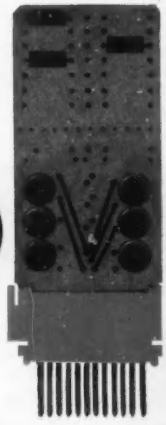
AT IBM, RAPID RECOGNITION AWAITS those engineers who can improve computer manufacturing by applying new advanced technological developments. Typical assignments now open include...

Cost Estimators and Standards Engineers to estimate manufacturing and engineering costs, develop estimating standards and write operation sequence sheets for the manufacture of components and subassemblies of complex data processing equipment.

Quality Engineers to apply modern scientific and statistical engineering methods in reviewing designs and specifications used in the manufacture of advanced electronic computer systems; to analyze product specifications in order to generate quality specifications and design statistical quality-control methods.

Test Engineers (Electronic) to plan and execute tests for the evaluation of electronic computer systems; to test computer systems and recommend design and logic changes in order to improve system reliability.

Semiconductor (Process) Engineers to develop manufacturing methods and techniques for production of transistors and other semiconductor devices.



COMPUTER MANUFACTURING

Electromechanical Designers to design high-speed electromechanical devices. Work involves magnetic circuit analysis, design of test circuitry, and vibration analysis.

Careers available in these related fields: Advanced Automation, Industrial Controls and Manufacturing Research and Methods.

Qualifications: B.S. or M.S. in Industrial, Electrical, or Mechanical Engineering—**or equivalent industrial experience.**

Manufacturing facilities are located in Endicott, Poughkeepsie, Kingston, and Owego, N.Y.; Rochester, Minnesota; Burlington, Vt.; Lexington, Ky.; and San Jose, California.

Write, describing background and qualifications, to:
Mr. R. E. Rodgers, Dept. 541N
IBM Corporation
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New York 22, New York

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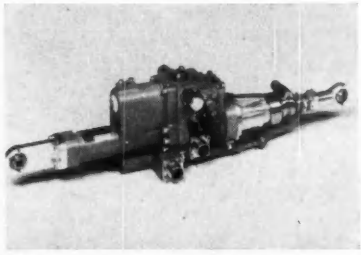
INTERNATIONAL BUSINESS MACHINES CORPORATION

cally operated diaphragm. Available in ⅛- to ½-in. pipe sizes as well as AND 10050 tube sizes 4 to 8, the valve will handle operating pressures to 10,000 psi, yet requires less than 50-psi control pressure. Various body and stem materials may be specified.—Dragon Engineering Co., Inc., Norwalk, Calif.

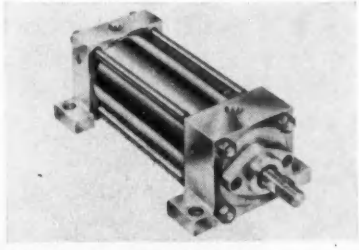
Circle No. 306 on reply card



MECHANICAL FEEDBACK

Photo above illustrates a new line of electrohydraulic servoactuators in which a simple mechanical feedback arrangement has eliminated the conventional electrical feedback transducer and associated amplifier. Piston position is fed back to the armature of the input force motor by means of springs and a precision motion reductive device. The difference between the input force and the spring feedback force is amplified by a variable orifice hydraulic amplifier which repositions a sliding spool valve. Units are available with pistons to 3 sq in. and strokes to 4 in.—Moog Servocontrols, Inc., East Aurora, N. Y.

Circle No. 307 on reply card



WELL CONSTRUCTED

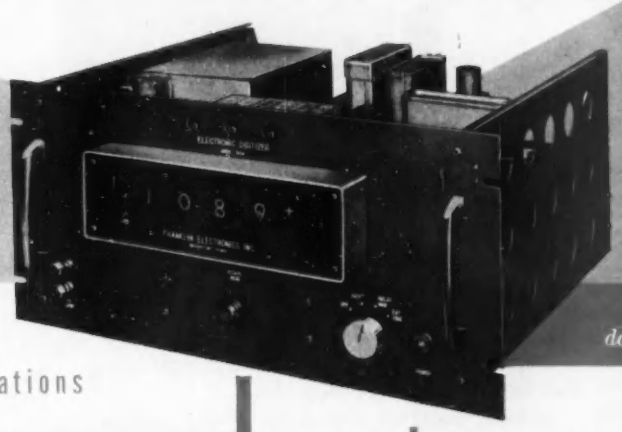
Photo shows one model from the new Powrmation series of low pressure air and hydraulic cylinders. Available in sizes from 1½ to 8 in., units feature welded mountings, a pressure-safe tube seal, and a unique check seal cushion that minimizes the destructive effects of heavy or high speed

long-term stability...ONE YEAR

MODEL 1310N A-to-D CONVERTER/VOLTMETER

There's never any need for exasperating knob twiddling with a Franklin Model 1310N. Magic? No, just plain practical design. All operating potentials, including the line voltage, are regulated before they're put to work. What's more, there are no stepping switches, relays or other mechanical components to introduce noise or delays . . . it's all-electronic for whisper-smooth voltage conversion . . . and with a stability never before equalled. The brief specs tell more.

MODEL 1310N, ALL ELECTRONIC ANALOG-TO-DIGITAL CONVERTER/VOLTMETER..... $2090*



request data sheet 2006

brief specifications

RANGES:	000.0 to 120.0 V dc. Input sensitivity: 0.1 V per digit. Matching amplifiers are available with minimum ranges of 1 mv per digit or 100 uv per digit.
RANGE AND POLARITY SWITCHING:	Optional automatic or manual (with amplifier).
ACCURACY (ABSOLUTE):	± one count (± 0.1% of full scale) after 10-minute warmup.
STABILITY:	Absolute accuracy is maintained for at least one year without calibration.

INPUT IMPEDANCE:	100 megohms.
READOUT TIME:	Maximum of 12.2 milliseconds to 120.0 volts full scale.
SPEED:	Up to 40 readings per second.
POWER:	100—125 V, 60 cps, 200 watts.
DIMENSIONS:	19" rack panel unit, 8¾" H x 15" D.
WEIGHT:	Approximately 50 pounds.

*Prices are F.O.B. BRIDGEPORT, PENNSYLVANIA.

FRANKLIN electronics, inc.
BRIDGEPORT PENNSYLVANIA
VAN NUYS CALIFORNIA

You count best when you count on FRANKLIN

NEW PRODUCTS

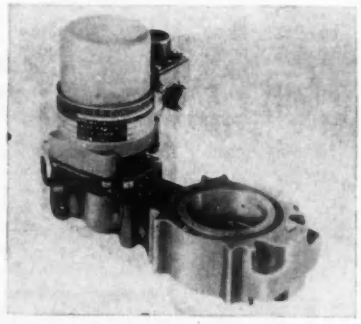
loads. Operating pressures are 250 psi air and 400 to 1000 psi hydraulic, depending on bore sizes.–Hanna Engineering Works, Chicago, Ill.

Circle No. 308 on reply card

HIGHER TORQUE

Pictured are two models from a new line of precision stepping motors capable of developing at least three times more torque than comparable devices. Called Syncramental Motors, these units may be used to drive potentiometers, counters, rotary switches, and other control mechanisms. Featuring low cost and long lift, these motors are available in unidirectional and bidirectional models, ranging in weight from 4 to 13 oz, with angular increments of 36 deg per pulse, speeds up to to 15 steps per sec, and starting torques to 2 lb-in. Probability of missing a step is 1 in 1 million.–G. H. Leland, Inc., Dayton, Ohio.

Circle No. 309 on reply card



USE TEFLON SEALS

A brand new family of gate valves, featuring mechanically loaded and retained Teflon seals, is now available for off-the-shelf delivery. Valves are of one-piece light-weight construction and will accommodate a variety of actuators. Through-mounting eliminates the possibility of thread damage to the valve body. In fuel handling ap-

ARE YOU MAKING THE SAME MISTAKE IN DEPOSITED CARBON RESISTORS?

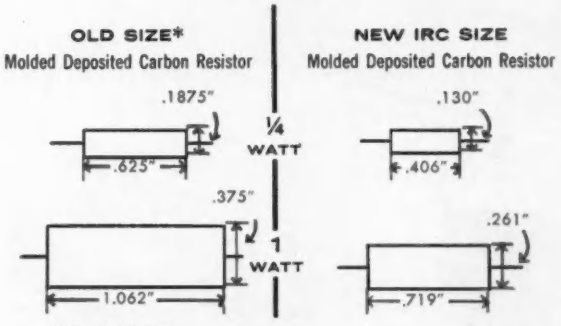
Switch to IRC Molded Deposited Carbon Resistors—"PRE-SHRUNK" for miniaturization.

If you have anything to do with miniaturizing components, be prepared for a pleasant surprise.

IRC has reduced the size of Molded Deposited Carbon Resistors in the 3 most popular wattage ratings at the same ambient, an improvement made possible through the use of a unique IRC alloy film and a new high-temperature coating.

This means that you can now choose a smaller unit with wattage equivalent to the one you formerly specified. Weight and space savings, as it happens, are especially significant in the most-used sizes.

COMPARE



*MIL NOMINALS

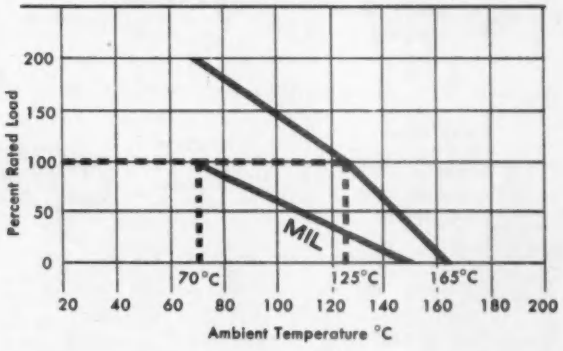
These SIZE REDUCTIONS also result in nearly corresponding weight reductions.

MIL Type	IRC Type	Length Nominal	Diam. Nominal	Min. Ohms	Max. Ohms	Max. Volts Continuous	WATTAGE MIL 70°C	WATTAGE IRC 70°C	WATTAGE IRC 125°C
RN60	MDA	.406	.130	10	5M	300	⅛	¼	⅛
RN65	MDB	.594	.203	10	5M	350	¼	½	¼
RN70	MDC	.719	.261	5	25M	500	½	1	½

IRC EXCEEDS MIL SPECIFICATIONS

IRC Resistors are designed for MIL-R-10509C Characteristic B requirements.

DERATING CURVE FOR IRC MOLDED RESISTORS



IRC HAS GREATER LOAD LIFE RESERVE

IRC Molded Deposited Carbon Resistors exhibit excellent heat dissipating characteristics. Size for size, IRC Resistors will run cooler under any load condition and take sudden overloads with very low permanent change. Load life is superior to that of hermetically sealed resistors which cost three times as much!

IRC HAS DOUBLE-BARRIER INSULATION

Resistance element is coated with a moisture-resisting material, then encased in a molded, break-resistant dielectric case which, though heavy-duty, is well within MIL size.

Write for Bulletin B-9C

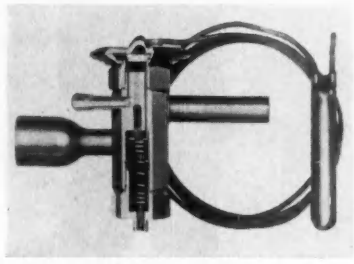
IRC

INTERNATIONAL RESISTANCE CO., Dept. 241, 401 N. Broad St., Phila. 8, Pa. • *In Canada:* International Resistance Co., Ltd., Toronto, Licensee

NEW PRODUCTS

plication, under continuous trouble-free conditions, the valves require no lubrication.—Whittaker Controls Div., Telecomputing Corp., Los Angeles, Calif.

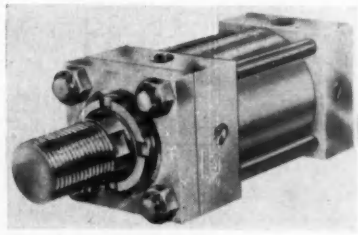
Circle No. 310 on reply card



HEAT PUMP VALVE

This Model 214 "flat-top" thermostatic expansion valve is designed to meet the severe reverse cycle pressures (up to 450 psig) found in heat pump systems. Under these conditions it has a life expectancy of over 100,000 cycles; for controlling the nominal 50 to 70 psig pressures found in standard refrigeration systems, this life is extended to over 1 million cycles. Units are available in three sizes with all solder-type connections.—Controls Co. of America, Milwaukee, Wisc.

Circle No. 311 on reply card



FASTER AND SMOOTHER

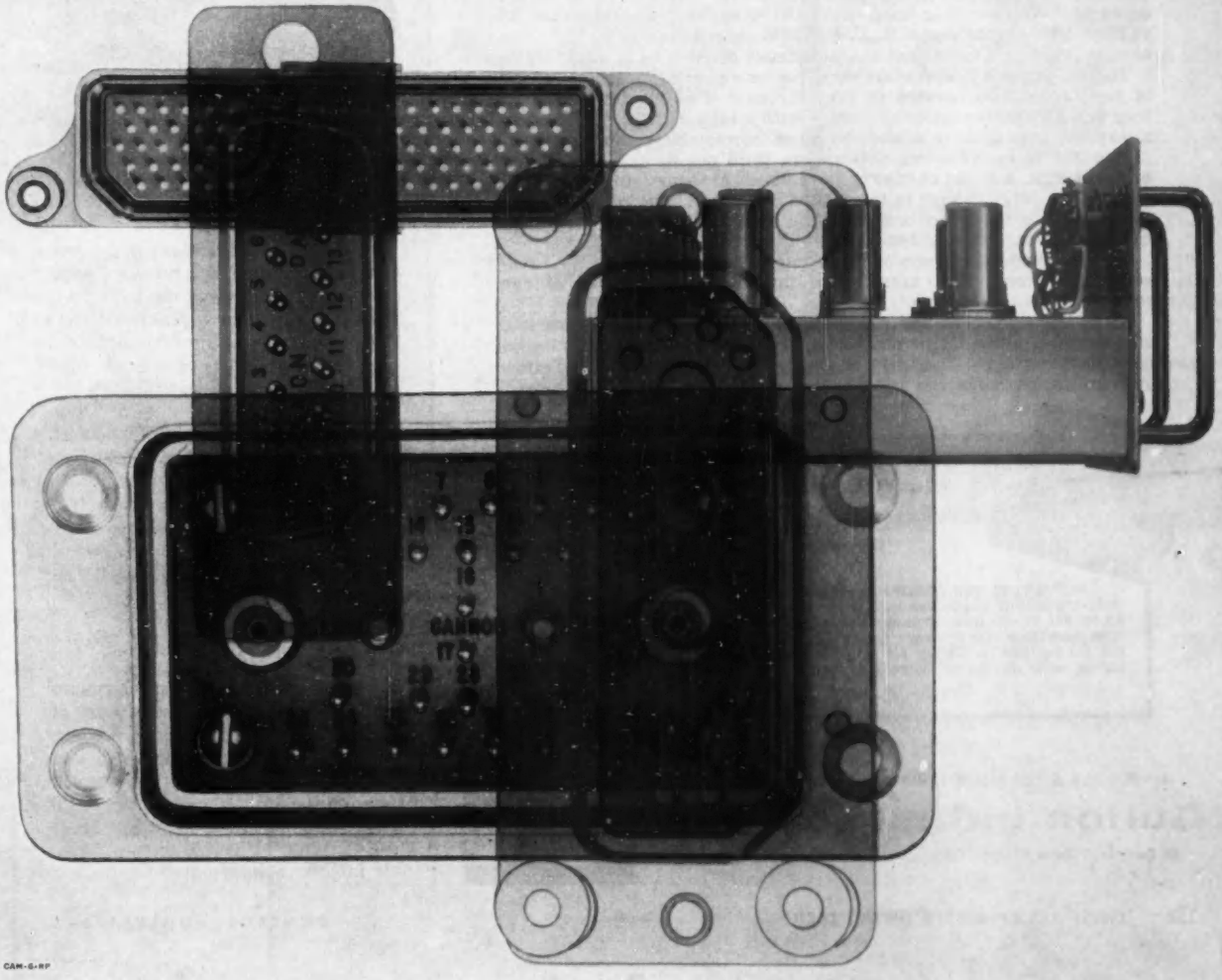
Available in 23 different mounting styles and 12 bore sizes from 1⅛ in. up to 12 in., a new line of heavy duty hydraulic cylinders offers maximum flexibility and smoother power output. Their smoother action results from a one-piece piston construction which eliminates air pockets and permits quick bleeding. Full area ports also aid in increasing speed. Units are designed for 2,000-psi operation but can be used in nonshock applications at pressures up to 3,000 psi.—The S-P Mfg. Corp., Solon, Ohio.

Circle No. 312 on reply card

CANNON PLUGS

The assembling of highly-flexible electronic systems and subsystems into a modular package . . . for fast inspection, testing, service, and replacement of components . . . calls for standardized-type plugs throughout the system. Reliability and optimum flexibility in shell designs and types of layouts are the design criteria for the more than 18 different basic Cannon Modular and Rack/Panel Plug Series. This Series is available in standard, miniature, or subminiature sizes . . . for standard or printed circuitry. Up to 180 contacts and a varied combination of contacts for control, audio, thermocouple, co-ax, twin-ax, and pneumatic connections. Single or double-gang. With or without shells. The Rack/Panel Series ranges from the tiny "D" subminiature to the heavy-duty DPD Rack/Panel Plug. For further information on Cannon Modular and Rack/Panel Plugs write for Cannon DP Catalog, Cannon Electric Co., 3208 Humboldt St., Los Angeles 31. Please refer to **Dept. 422**, Factories in Los Angeles, Santa Ana, Salem, Toronto, London, Paris, Melbourne, Tokyo. Distributors and Representatives in the principal cities of the world.

Maximum Flexibility for Modular and Rack/Panel Applications



CAM-G-RP

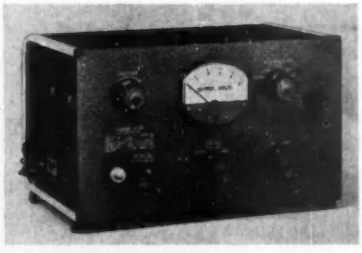
NEW PRODUCTS

PLUS. . . .

(313) A new low cost line of eddy current coupling **adjustable drives** from 5 to 100 hp has been announced by the **General Electric Co.**, Schenectady, N. Y. . . . (314) **Waterman Hydraulics Corp.**, Evanston, Ill., now offers a line of four-way ac **solenoid valves** featuring high capacity, light weight, and low current consumption. . . . (315) An electrically operated **high pressure valve**, developed by **Marotta Valve Corp.**, Boonton, N. J., permits remote control of 4,500-psi air or nitrogen over a wide temperature range.

Circle No. 313, 314, or 315 on reply card

RESEARCH, TEST, & DEVELOPMENT



LOW COST NOISE

This type 1390-B random noise generator, priced at $205, provides wideband noise of uniform spectrum level and is suitable for a variety of electrical and mechanical test applications. Noise source consists of a single 6D4 gas discharge tube. Front panel switch permits selection of shaping filters to provide outputs in the 20 kc, 500 kc, or 5 Mc range. Instrument also features a built-in 80-db attenuator to provide metered outputs from over 3 volts to below 30 μv.—General Radio Co., West Concord, Mass.

Circle No. 316 on reply card

ULTRASENSITIVE

The model 700B mass spectrometer leak detector features a sensitivity of 10 to minus 13 standard cc per sec. Designed for measuring leaks in vacuum, pressure, or hermetically sealed systems, the unit is said to be 1,000 times more sensitive than any other leak detector. Possible testing methods include helium envelope, helium

GD700 SERIES
GAS-O-DOME REGULATORS

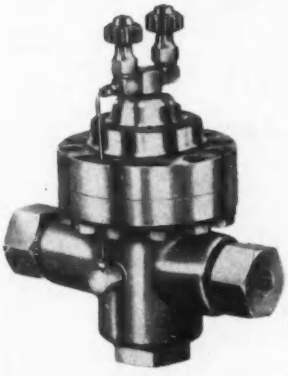
Models in bronze or stainless steel
Pilot operated type
Max. inlet: 7000 to 10,000 psig.
Outlet range: 10-150 to 400-7000 psig.
Flows to 250 scfm.
Low torque: 35 inch-lb. at 7000 psig.
Panel mounting
Bulletins R12 and R18.

BPR SERIES
BACK PRESSURE REGULATORS

Models in bronze or stainless steel
Adjustable relief ranges: From 25-500 psig. to 2000-10,000 psig.
Panel mounting
Bulletin R19

LR SERIES LOADER REGULATORS

Models in bronze or stainless steel
Max. inlet: 7000 to 10,000 psig.
Outlet range: 5-200 to 200-10,000 psig.
Flow: 10 scfm.
Low torque: 35 inch-lb. at 7,000 psig.
60 inch-lb. at 10,000 psig.
Panel mounting
Bulletins R11 and R17



GD90, GD100A AND GD200A
SERIES GAS-O-DOME REGULATORS

Models in bronze or stainless steel
Compensated, high-flow type
Max. inlet and outlet: 6000 psig.
Flows to 80,000 scfm.
Remote control and/or
panel mounting provisions
Bulletin R18

LV-10 LOADER VALVE

Made in bronze only.
Inlet and outlet: 7000 psig.
Flow: 10 scfm.
Fast finger-tip control:
30° clockwise, loads;
30° counter-clockwise, bleeds.
Panel mounting
Bulletin LV-10

GD60 AND 80 SERIES
GAS-O-DOME REGULATORS

Models in bronze
(stainless steel on request)
Inlet and outlet range: 2500 to 10,000 psig.
Flows to 1500 scfm.
Remote control and/or
panel mounting provisions
Bulletin R10A

VICTOR High pressure gas controls

Victor offers you choice of these and many other gas regulators for a wide variety of applications.

All come cleaned for oxygen service; LOX cleaned when specified. Operating temperature ranges: —67° F. to +250° F. (storage —80° F.) Modifications for special applications. Write now for Victor High Pressure Regulator bulletins and Regulator Inquiry Form 361A.

Mfrs. of high pressure and large volume gas regulators; welding & cutting equipment; hardfacing rods; blasting nozzles; cobalt & tungsten castings; straight-line and shape cutting machines.

VICTOR EQUIPMENT COMPANY MISSILE DIVISION 63

844 Folsom St., San Francisco 7 • 3821 Santa Fe Ave., Los Angeles 58 • 1145 E. 76th St., Chicago 19
J. C. Menzies & Co., Wholly-Owned Subsidiary

CIRCLE 139 ON READER SERVICE CARD

NEW PRODUCTS

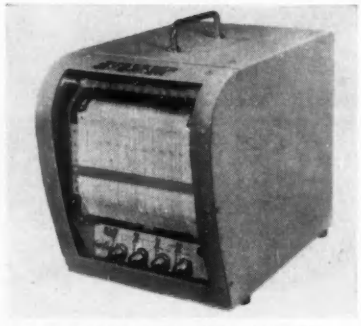
probe, vacuum chamber, and sample probe. Complete unit weighs approximately 650 lb., draws from 12 to 22 amps at 115 vac and sells for $12,800. —Crosby-Teletronics Corp., Westbury, N. Y.

Circle No. 317 on reply card

PORTABLE AND SENSITIVE

This compact instrument, the Model 213 hydrocarbon detector, measures carbon impurities in air or gases, and has an adjustable full scale range of 0 to 1 ppm up to 0 to 10 percent. Its response time is less than 2 sec. Unit weighs 47 lb fully equipped, and according to the manufacturer, can be operated by nontechnical personnel after brief instruction.—Perkin-Elmer Corp., Norwalk, Conn.

Circle No. 318 on reply card

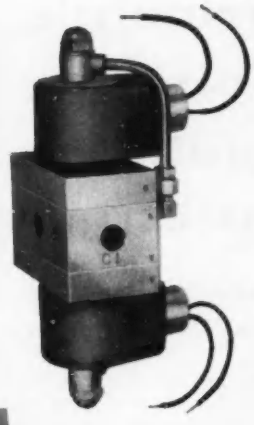


TWO-CHANNEL RECORDER

Photo above shows the portable version of a new two-channel strip chart recorder developed for use with strain gages, thermocouples, and similar transducers. Features include an adjustable 9- to 120-mv span, gear shift selection of chart speeds, a 0.8-sec balance time and a sensitivity within

New 3 Position,
4 Way Solenoid Valves
Feature Dead Tight
(Poppet Type) Seating

ELIMINATE PISTON DRIFT



ASCO's new 3 position 4 way (Bulletin 8347) permits no leakage on air or liquids, assures precision positioning and positive locking of cylinder piston. Graduated (inching) or full stroke of piston may be obtained by regulating the length of time each solenoid is energized. When both solenoids are de-energized, the valve assumes a center position. All orifices are blocked, locking the cylinder piston at any point in the stroke.

Simple valve design (only moving parts are 2 solenoids and 4 diaphragms) and overall rugged construction provide millions of trouble free operations. These new valves can be mounted in any position, are available in ¼" and ⅜" pipe sizes, handle air, water and oil at pressures to 250 p.s.i. Bulletin 8347 Valves are stocked for immediate delivery.

ASCO Solenoid Valves are stocked at the Florham Park Factory, and at warehouses in Chicago and Los Angeles. **WRITE** for catalog literature on the new Bulletin 8347, and for the new ASCO Stock List and Selection Guide (Publication 506) listing the world's largest stock of solenoid valves for immediate delivery.

ASCO Valves

Automatic Switch Co. 50-G HANOVER RD., FLORHAM PARK, N. J., FRONTIER 7-4600

AUTOMATIC TRANSFER SWITCHES • SOLENOID VALVES • ELECTROMAGNETIC CONTROL

ASCO

CIRCLE 141 ON READER SERVICE CARD

SYLVANIA D-1820 is the forerunner of an out-

NEW PRODUCTS

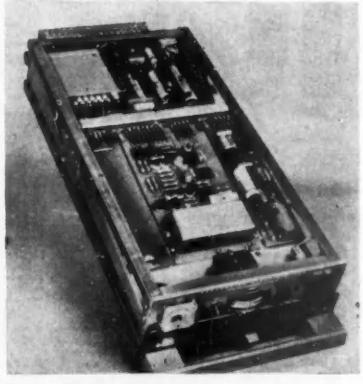
0.25 percent of span. Unit weighs 25 lbs and requires 75 watts at 115 volts, 60 cycles. Basic model sells for $850, single channel version for $435.—Systron Corp., Concord, Calif.

Circle No. 319 on reply card

PRECISION DC VOLTMETER

The Model 301 E precision high impedance voltmeter is said to be capable of sensing voltages in circuits where current flow is as low as 60 electrons per sec. Its unusually high input impedance (over 10^{17} ohms) and precision amplifier assures a voltage flow accuracy within 0.02 percent of the input voltage. Applications include the study and testing of semiconductor devices, molecular electronics, atomic physics, and electrical circuit design. Unit will handle dc inputs to plus or minus 250 volts or low-frequency ac inputs to 500 volts, peak to peak.—Halex Inc., El Segundo, Calif.

Circle No. 320 on reply card

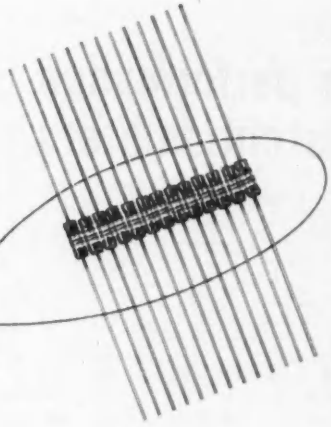


LOW POWER DRAIN

Selected for the ground data reduction in the R&D phase of the Minuteman ICBM project, this new transistorized subcarrier discriminator is the first of a complete line of solid-state telemetry units. Its phase-lock circuitry provides optimum performance capabilities and coherent detection. Replaceable plugboard construction improves reliability and simplifies maintenance. Features include a continuously adjustable output voltage control and a dynamic input range of 10 mv to 10 volts. Power drain is less than 27 watts.—Data-Control Systems, Inc., Danbury, Conn.

Circle No. 321 on reply card

Now available in commercial quantities!



Sylvania D-1820 germanium High-Speed Switching Diode

4 mμSECS

GUARANTEED MAXIMUM RECOVERY TIME!

SYLVANIA D-1820 is the forerunner of an outstanding family of diodes, designed, produced and controlled specifically for logic circuitry. The cost of this new SYLVANIA diode is low enough to make it especially attractive for use in quantity-produced electronic computers. SYLVANIA D-1820, and the circuits designed around this diode, feature:

high-speed operation – with recommended circuits, all units are guaranteed to provide a maximum recovery time of 4 millimicroseconds. However, recovery times of 2.5 millimicroseconds are typical.

long-life performance – proved in 1000-hours operating and 7000-hours storage life tests.

high reliability – basic point-contact structure has been field-proved for more than a decade. Withstands environmental conditions of shock and vibration.

exceptional uniformity of electrical characteristics–assures complete interchangeability within the type–result of modern automated-production techniques employed in the manufacture of SYLVANIA D-1820.

economy – SYLVANIA pioneered the field of germanium point-contact diode manufacture, has "know-how" of superior-quality, large-quantity economical production. SYLVANIA is able to pass these savings on to you.

simplicity–diode-logic circuitry is relatively uncomplicated, requires few components. It reduces computer construction costs. It adds to equipment reliability.

compactness–SYLVANIA D-1820 "package" is miniature all-glass.

availability–units can be supplied immediately through your local Sylvania Semiconductor Distributor or through your local Sylvania Field Office.

Complete sales information on quantity prices, delivery and sampling for your own evaluation is available from your local Sylvania Semiconductor Distributor or Field Office. For engineering data sheets on the new Sylvania D-1820 High-Speed Switching Diode or on any Sylvania Semiconductor Device, write Sylvania Semiconductor Division, Dept. 13-2, Woburn, Mass.

ELECTRICAL CHARACTERISTICS— SYLVANIA D-1820

Absolute Maximum Ratings*	Typical Operating Conditions*
Fwd. Volt .....1.3 V†	Fwd. Volt.....0.9 V
Fwd. Curr. .....50 mA	Fwd. Curr. .....2.0 μA
Back Volt .....20 V	Rev. Recovery.....2.5 mμs
Pwr. Diss. .....80 mW	

†at 10 mA *at 20° C.

SYLVANIA

Subsidiary of **GENERAL TELEPHONE & ELECTRONICS**

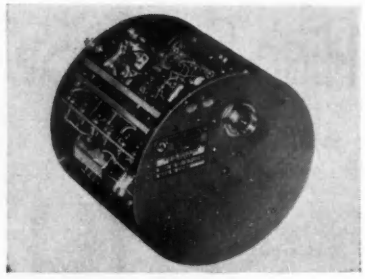
NEW PRODUCTS

PLUS. . . .

(322) **Pyrometer Instrument Co., Inc.,** Bergenfield, N. J., has announced development of a new **pyrometer calibrating set** which permits accurate and simultaneous calibration of any two optical pyrometers. . . . (323) **Scientific-Atlanta, Inc.,** Atlanta, Ga., now makes an electrical **analog computer** especially designed to solve Fourier integrals.

Circle No. 322 or 323 on reply card

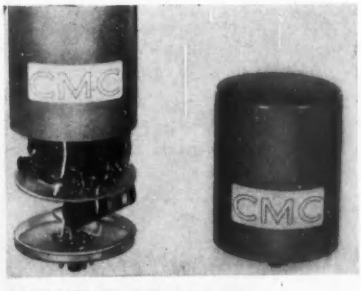
POWER SUPPLIES



SHORT TERM POWER

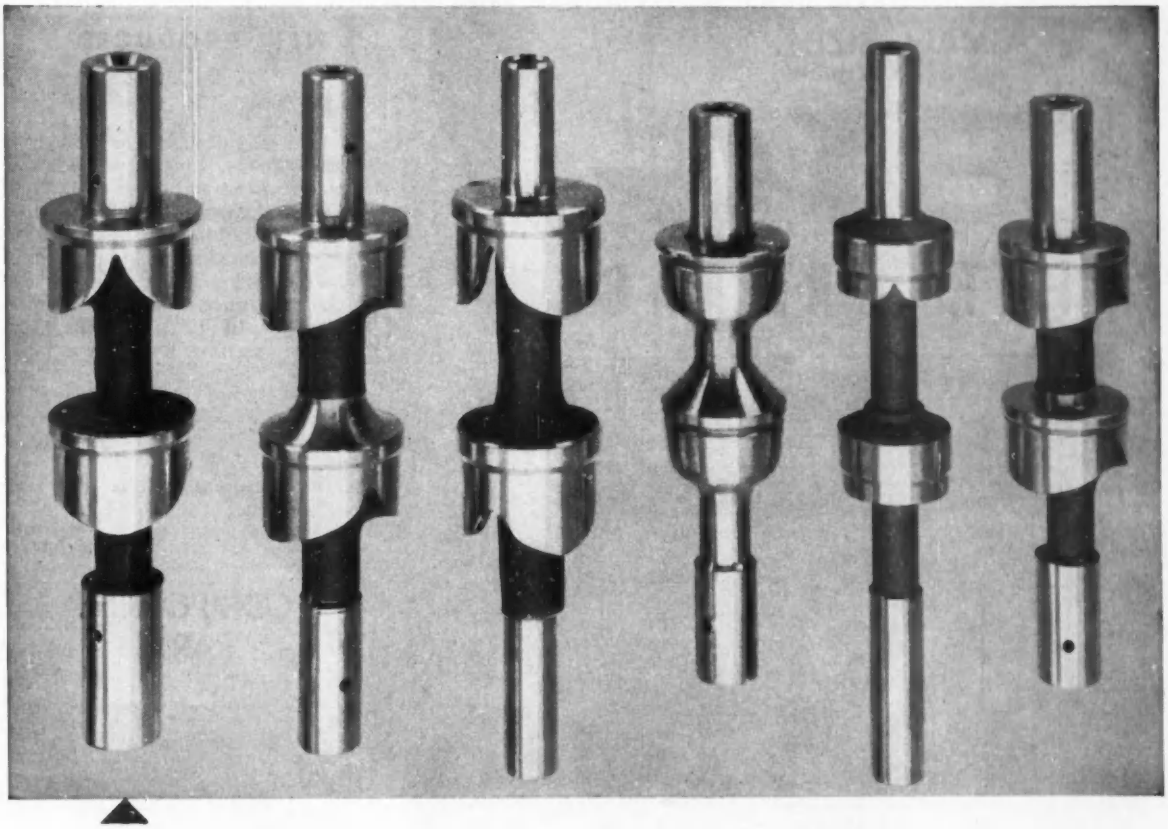
Designed to operate from a self-contained 28 vdc silver cadmium battery, this new static inverter-converter provides three separate outputs: 115/200 volts, 3200 cps, 3-phase at 1 kva; 300 vdc at 0.5 amp; and 150 vdc at 1.0 amp. For intermittent operation, unit features a thermodynamically reversible heat sink which uses an exotic solid-to-liquid coolant to produce a delay in temperature rise. For continuous operation it will provide 1300 va for 4 min.–Magnetic Amplifiers Inc., New York City.

Circle No. 324 on reply card



CURRENT STANDARD

Temperature stability of this new solid-state constant current source is



Inner secrets of inner valves

FACTS EVERY CONTROL VALVE USER SHOULD KNOW

This is a rare photograph . . . presented in a completely unretouched form. It shows the inner valve of leading makes of diaphragm control valves. The inner valve determines the control result.

The most amazing fact is the size . . . all are *listed* as two inch valves. All are high lift. But compare them.

Note the KIELEY & MUELLER inner valve at the far left. It equals the others on every point of consideration; exceeds on many. Look at the diameter across the skirt . . . that's one reason for the remarkable C_v of K&M valves. Look at skirt length; the solid, not fabricated, design. Measure the rugged guide posts and the large column. Examine the machining and the super-finishing.

It's no wonder . . . K&M is *the valve that likes to be compared.* It's a better valve and a better value by every measure of comparison.

FOR THE COMPLETE FACTS . . .
write for the K&M Valve Engineering Data Catalog, Bulletin CV53.

diaphragm control valves

K&M

Our 78th Year

KIELEY & MUELLER, INCORPORATED

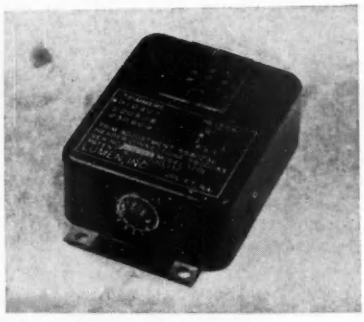
Oldest Pressure and Level Control Valve Manufacturer

64 Genung Street, Middletown, New York

said to be greater than that of a standard cell. Designed for industrial potentiometers and other applications where load change is small, its output voltage varies less than 0.001 percent per volt change in the supply voltage and less than 0.0025 percent per deg C. Performance is based on an input voltage of 107-127 volts, 50-60 cps and an operating temperature range of 0-60 deg C. Units are available for any current between 0 and 15 ma and any load up to 400 ohms.—Control Methods Co., Rhinebeck, N. Y.

Circle No. 325 on reply card

COMPONENT PARTS



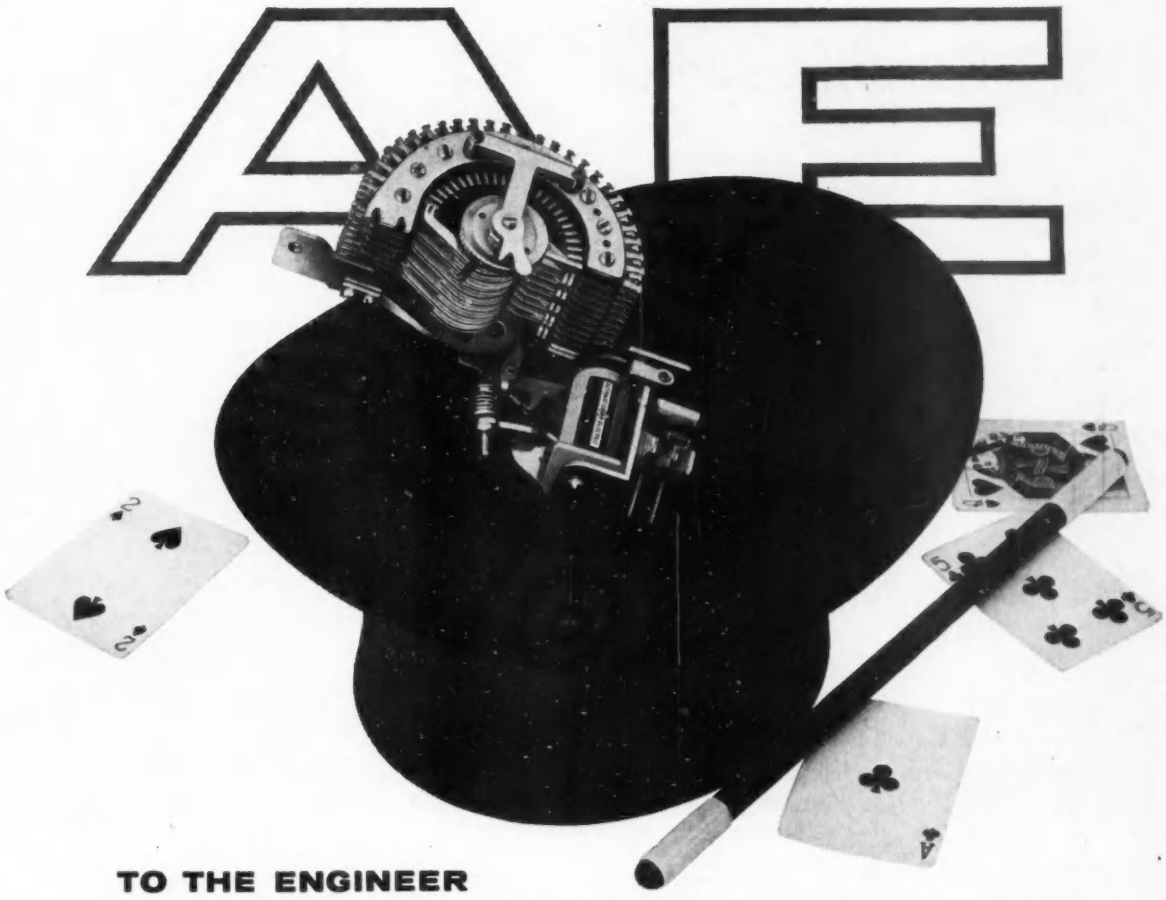
FLEXIBLE AMPLIFIER

Powered from a 28-vdc supply this Model 1201 magnetic amplifier features an adjustable network which adapts it to a wide range of input voltages and impedance. Typical inputs include thermocouples, ranges as low as 0-1 mv, and resistance thermometer bridges with ranges up to 0-500 mv. Its output in all cases is 0-5.0 vdc. Both linearity and zero shifts are within 1 percent of full scale. Unit has a maximum output impedance of 1,000 ohms and a maximum voltage gain of 5,000.—Lumen, Inc., Joliet, Ill.

Circle No. 326 on reply card

60-CYCLE SYNCHROS

A complete series of 60-cycle synchro transmitters, differentials, and control transformers has been designed for use in industrial servosystems. Stainless steel housing, shaft, and ball



TO THE ENGINEER

who can use a little honest trickery

There's more than one way of skinning a cat —or making ideas *work* automatically. And AE has a bag-full.

That's because AE has had years of experience in making relays and stepping switches work wonders in automatic telephone exchanges—*and* in automatic control devices.

If you can use some down-to-earth magic in your designs, AE engineers will be glad to help. And you may well find that their suggestions can simplify the control package.

They can also show you why AE relays and stepping switches cost you less in the long run.

For instance, the AE Type 45 Stepping Switch, illustrated, has a free-floating pawl that never binds, never breaks, eliminates the necessity of ever readjusting armature stroke, does away with double-stepping or overthrow. And the switch usually outlasts the equipment it's built into!

You'll also be interested in knowing that AE is equipped to deliver completely wired and assembled control units designed to your specifications.

Want more information? Just write the Director, Industrial Products Engineering, Automatic Electric, Northlake, Illinois. Ask for Circular 1698-H: *Rotary Stepping Switches;* Circular 1702-E: *Relays for Industry;* and our new 32-page booklet on *Basic Circuits.*

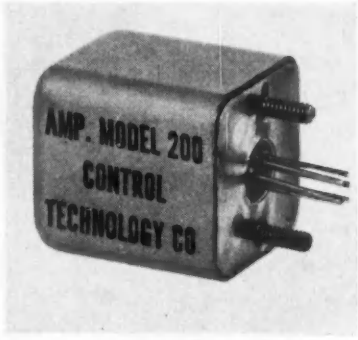
AE CAN DO

AUTOMATIC ELECTRIC

Subsidiary of
GENERAL TELEPHONE & ELECTRONICS

bearings and corrosion resistant nickel steel laminations provide reliable operation in corrosive atmospheres. Although they weigh just 4 oz., these units are characterized by high accuracy, rugged performance, and long life.—Kearfott Div., General Precision, Inc., Little Falls, N. J.

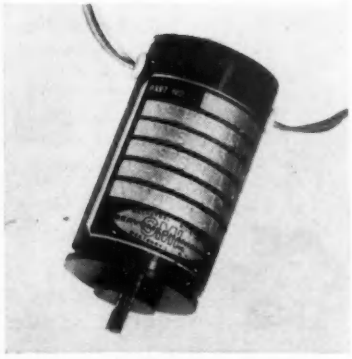
Circle No. 327 on reply card



DRIVES 3.5-WATT MOTORS

Just 1-in. square by 1⅛ in. long, this tiny Model 200 servoamplifier will drive 2-watt or 3.5-watt servomotors from a low level 400-cycle signal at ambient temperatures between minus 55 and 125 deg C. Maximum gain is 2,500 and can be adjusted by adding an external resistor. Unit operates on a 28-vdc supply and meets all environmental requirements of MIL-E-5272A.—Control Technology Co., New York, N. Y.

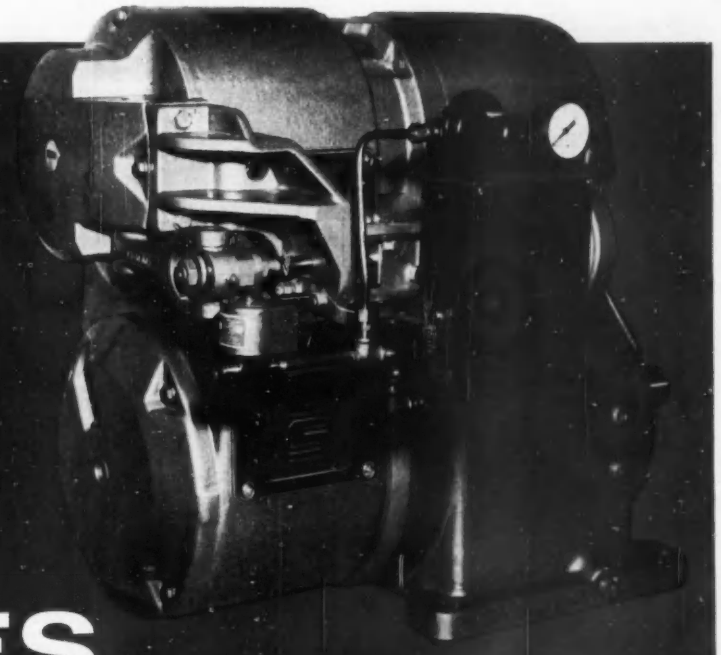
Circle No. 328 on reply card



OFFERS TWO SPEEDS

This new combination 4- and 8-pole dual speed synchronous motor features a size 11 frame, an overall length of less than 2 in., and an ambient tem-

AIRtrol: automatic process control with REEVES VARI-SPEED MOTODRIVES



REEVES AIRtrol, in an open or closed loop system, automatically and continuously corrects operating speeds to compensate for variations in materials or processes. AIRtrol controls variable output speeds from temperature, liquid level, pressure, weight, peripheral speed and proportional flow signals. Here are important reasons why REEVES AIRtrol on REEVES Vari-Speed Motodrives, are performing efficiently on conveyors, pumps and machine tools . . . and in process industries handling solids and liquids.

- Exclusive contoured cam design results in output speed in direct proportion to instrument air signal. This permits linear (straight line) output speed over the entire output speed range of the drive.
- Cam also provides a sensitive and stable control throughout the speed range . . . automatically.
- AIRtrol operates on a 3—15 psi. air signal from any standard process-instrument. Exclusive "Span Adjustment" feature makes it possible to use the full signal . . . locking the 3 psi. signal to minimum speed and 15 psi. to maximum speed of the motodrive. This applies to units of 2:1 speed range, as well as 10:1.
- REEVES AIRtrol is available on all REEVES Vari-Speed Motodrives—¼ hp. through 40 hp., 2:1 through 10:1 speed range, with variable output speeds as high as 4660 to as low as 1.71 rpm.

For complete information on REEVES AIRtrol, call your nearest Reliance Sales Engineer.

G-1604

Product of the combined resources of Reliance Electric and Engineering Company and its Master and Reeves Divisions

RELIANCE ELECTRIC AND ENGINEERING CO.

DEPT. 522A, CLEVELAND 17, OHIO
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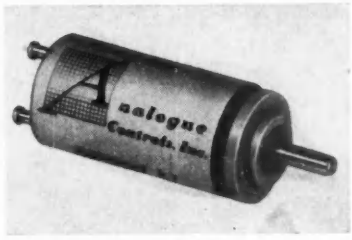
Duty Master A-c. Motors, Master Gearmotors, Reeves Drives, V★S Drives, Super 'T' D-c. Motors, Generators, Controls and Engineered Drive Systems.

NEW PRODUCTS

perature range from minus 55 to plus 85 deg C. Input voltage for either 12,000- or 6,000-rpm operation is 115 volts, 400 cycles single phase. Double sets of leads permit external switching. Total weight of the unit is 3.8 oz. – Servomechanisms, Inc., Westbury, N. Y.

Circle No. 329 on reply card



TINY 10-TURN POT

Available in all conventional resistance values as well as in nonlinear versions, this Model 0610M, 10-turn potentiometer, meets or exceeds the environmental requirements of MIL-E-5272B and NAS-710. Only ½ in. in diameter, it features low-leakage construction, stop torque limits of 25 oz-in., and a temperature range of minus 55 to 125 deg. C.–Analogue Controls, Inc., Hicksville, N. Y.

Circle No. 330 on reply card

HIGH GAIN PREAMP

In a single stage this Model 761 60-cycle relay magnetic preamplifier will deliver 0.3 watts of output power from low level dc control signals of less than 3.0 μwatts. Possible applications include the driving of small power relays from thermistor bridges, photocells, null detectors, and similar low energy signals. Unit contains three independent and isolated signal wind-

Replace Complete Trim Without Removing Valve From Line!

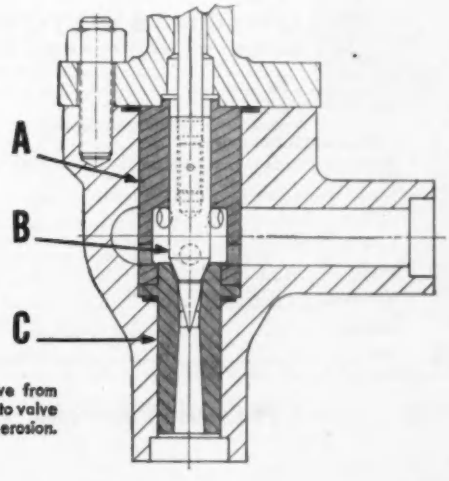
Rockwell-built Republic V-10 valves with Quick-change Trim save many hours of downtime on severe energy conversion applications with pressure drops up to 3500 lbs.

The Republic V-10 angle valve for high-pressure liquid or steam regulating services offers unique valve maintenance advantages because of its Quick-change Trim construction.

Quick-change Trim in the V-10 valve makes it possible for you to replace the valve seat, inner valve and guide in little more time than is required to dismantle and reassemble a bolted joint. No time is required for lapping the seating surfaces of the valve, since this is done in advance. *And you can make this quick trim change in minutes without removing valve from the line.* The savings to you are considerable in downtime and maintenance expense.

Republic V-10 Valves are available with either welded seat or replaceable seat, in addition to the Quick-change Trim design, with bolted or pressure seal bonnets. V-10 valve contours are designed to produce not only the desired regulating characteristics, but also to reduce erosion damage and noise as well. Precise manufacture and long-life materials make Republic regulating valves perform better, last longer, with less maintenance. For additional information, contact your nearest Republic Representative, or write to Republic Flow Meters Company, 2240 Diversey Parkway, Chicago 47, Illinois. In Canada: Republic Flow Meters Canada, Ltd., Toronto. Subsidiary of Rockwell Manufacturing Company.

Rockwell-Republic V-10 regulating valve with Type J-1 positioner is designed for rugged high-pressure liquid or steam service.



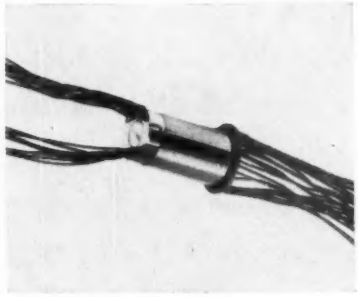
Quick-change Trim feature makes it possible to replace the seat guide (A), inner valve (B), and seat (C), without removing valve from the line. Seat extends to valve outlet to prevent body erosion.

REPUBLIC INSTRUMENTS AND CONTROLS
more fine products by
ROCKWELL

NEW PRODUCTS

ings, two of which will balance for push-pull inputs. Operation requires 0.6 watts from a 26-volt, 60-cycle supply.—Acromag, Inc., Southfield,

Circle No. 331 on reply card

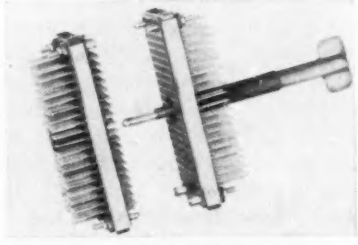


TINY SLIP RINGS

Shown is the first of a new line of microminiature slip ring assemblies. The complete package contains 21 rings, 42 brushes, and 2 bearings, and is actually smaller than an ordinary pencil eraser. Features include stainless steel case, Teflon insulated leads, an integrally molded rotor, and a temperature range from minus 65 to plus 350 deg F. Current rating on six of the rings is 2 amps; remaining rings are rated at 1 amp.—Slip Ring Co. of America, Los Angeles, Calif.

Circle No. 332 on reply card

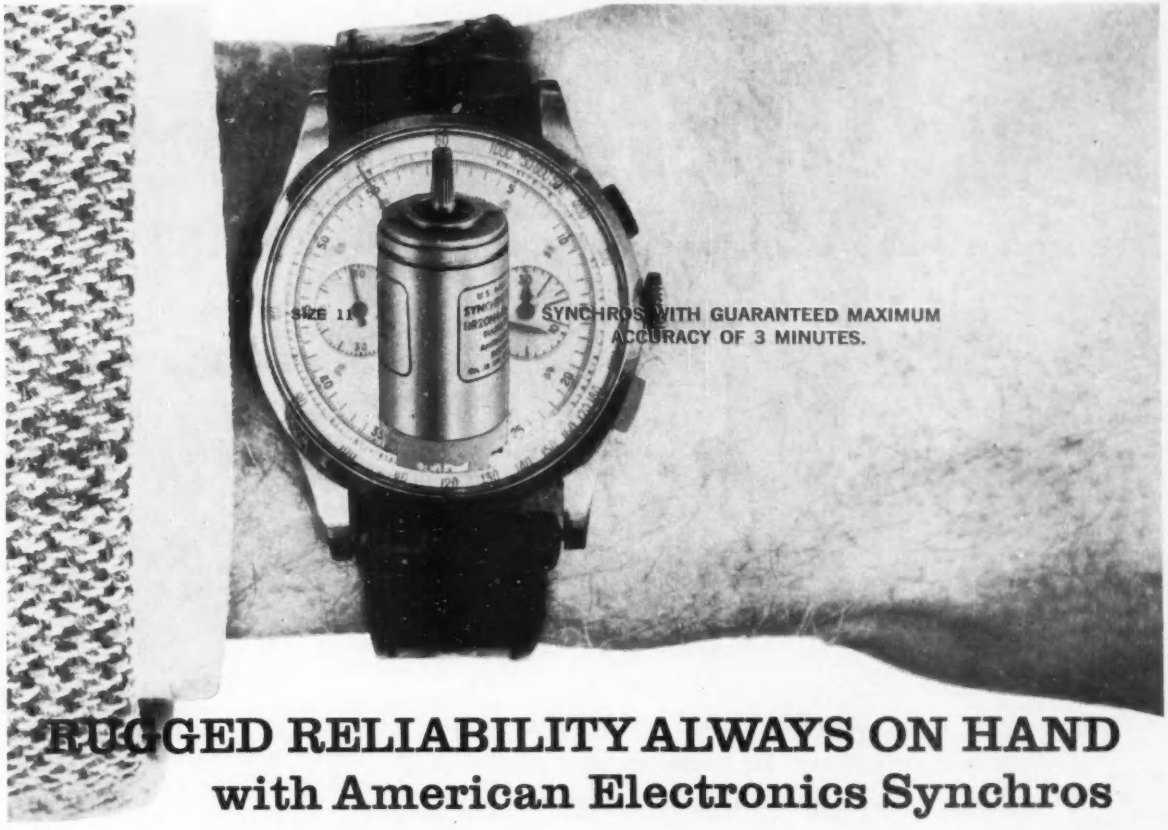
ACCESSORIES & MATERIALS



SCREWLOCK CONNECTORS

Features of this 152-contact, center screwlock connector include high dielectric and mechanical strength, positive locking action, and optional terminal types. Its closed-entry contacts provide increased reliability and

outlet to prevent body erosion.



RUGGED RELIABILITY ALWAYS ON HAND
with American Electronics Synchros

You can depend on high performance and dependability at all times with the complete line of control synchros (transformer differential and transmitter), produced by the Instrument Division of American Electronics, Inc. Used as a family or independently in system applications, these units will operate over a temperature range of −55° to +125°C . . . and can be supplied to operate up to 200°C.

Available in frame sizes from 8 to 25 these synchros meet and exceed the stringent standards of MIL-SPEC. 20708.

The key to proven reliability lies in the quality features engineered and manufactured into each unit. Greater stability and corrosion resistance is accomplished by stainless steel housings. Encapsulated unit construction and hermetically sealed windings are used to withstand the extremes of vibration and shock. Through-bore construction means fewer parts and less space in which damaging moisture may collect.

SIZE 11 ELECTRICAL DATA

	11E22M-81G (Transformer)	11E22M-01F (Transmitter)	11E22-81J (Differential)
PRIMARY	Stator	Rotor	Stator
INPUT (VOLTS)	11.8	115	11.8
TEST (VOLTS)	10.2	115	10.2
FREQUENCY (CPS)	400	400	400
Z_{RO} ROTOR IMPEDANCE (STATOR OPEN CIRCUITED) (OHMS)	3340 /79°	2000 /80°	107 /78°
Z_{SO} STATOR IMPEDANCE (ROTOR OPEN CIRCUITED) (OHMS)	570 /80°	18 /79.5°	92 /80°
MAX. NULL VOLTAGE (FUNDAMENTAL) (VOLTS) (TOTAL) (VOLTS)	.030 .040	.015 .020	.015 .020
MAXIMUM ERROR (MINUTES)	3	3	3
TRANSFORMATION RATIO (R/S) ±4%	2.203	.103	1.154
PHASE SHIFT (DEGREES)	5	6	6
D. C. RESISTANCE (OHMS) STATOR ROTOR	60 385	3 185	11 19.0

FOR INFORMATION ON SIZE 8 AND OTHER SIZES WRITE FOR SPECIFICATIONS.

For complete information on the outstanding performance of the complete line, write

AMERICAN ELECTRONICS, INC.

INSTRUMENT DIVISION

9503 WEST JEFFERSON BOULEVARD, CULVER CITY, CALIFORNIA

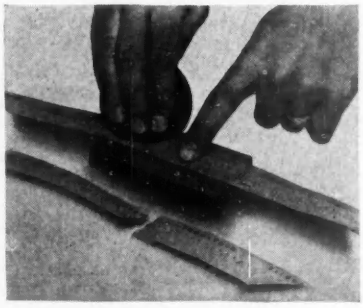
CIRCLE 153 ON READER SERVICE CARD 153

NEWEST HOW-TO-write-performance

NEW PRODUCTS

maintain a low millivolt drop under constant insertion pressure. Body material is molded from glass-filled diallyl Phthalate. Other models in the same series are available with 104, 78, or 34 contacts.—DeJur-Amsco Corp., Long Island City, N. Y.

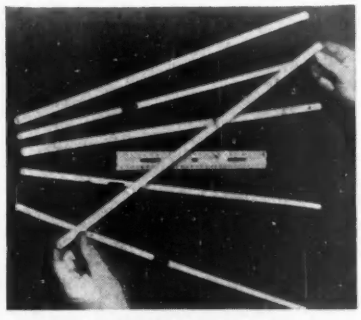
Circle No. 333 on reply card



TAPE SPLICER

This new splicing kit for paper, aluminium, Mylar, or other perforated tapes consists of a small metal block with pins to engage the feed holes of any standard tape, prepunched pressure-sensitive tape for butted splices, a tube of cement for overlapping splices, and a rubber pressure pad. Simple to use, the complete kit sells for $10.—Unicorn Div., Computer Measurements Co., Sylmar, Calif.

Circle No. 334 on reply card



HIGH MELTING POINT

Beryllium oxide ceramic tubing, for insulating and protecting thermocouples and other sensing elements, is now available in stock lengths up to 21 in. (24 in. on special order) and four bore sizes ranging from 5 mm to $\frac{7}{8}$ in. Wall thicknesses range from 1 mm to $\frac{1}{8}$ in. Material features greater strength above 2,000 deg. F than any other ceramic. — National Beryllia Corp., North Bergen, N. J.

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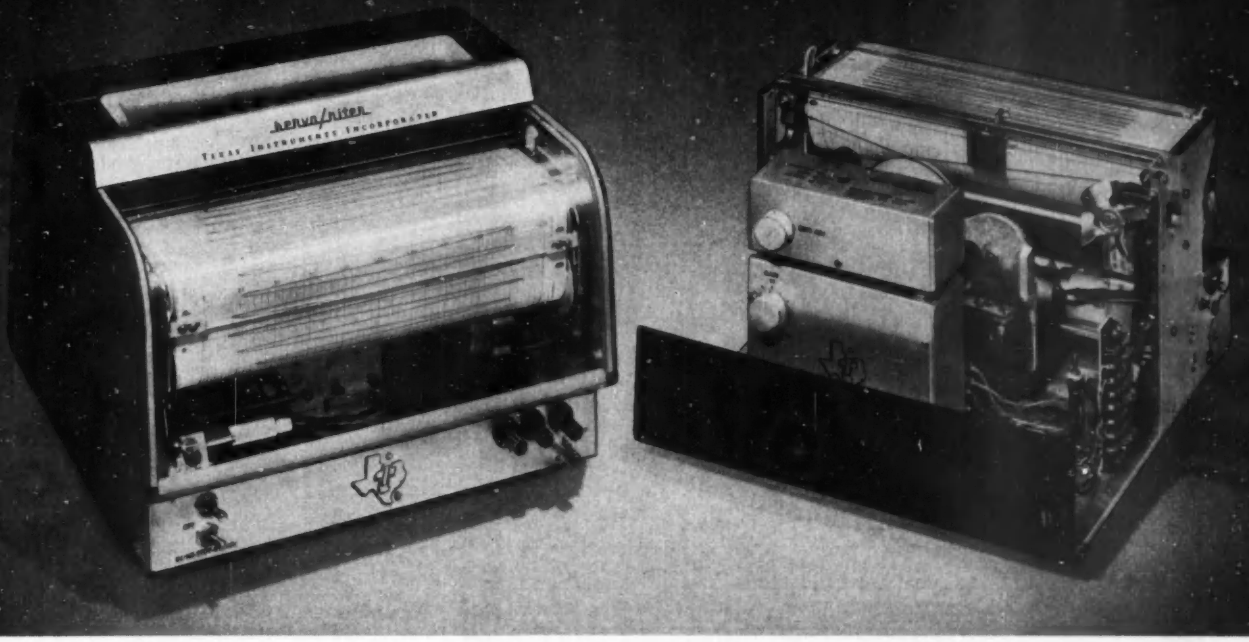
NEWEST way to write performance . . .

servo/riter*

SELF-BALANCING POTENTIOMETRIC RECORDER



NO OTHER RECORDER OFFERS YOU AS MANY HIGH PERFORMANCE FEATURES . . . at any price!

The old cliché, "You can pay more but you can't buy better" was never more applicable than in the new "servo/riter" recorder. Texas Instruments has developed a self-balancing potentiometric recorder that incorporates *premium* engineering refinements, sensitivity, reliability and quality construction as *standard* equipment.

High-Sensitivity — Standard electrical span of 2.5 millivolt d-c with off-balance input resistance of 4 megohms gives a power sensitivity of better than 10^{-17} watts.

Fast Pen Speed — Span step response is less than 0.5 second.

High Interference Rejection — Good filtering provides high orders of rejection to common-mode d-c and all types of 60 cps interference. Guard shields permit making full-accuracy measurements at hundreds of volts above ground.

Long-Term Reliability — Tube life is prolonged by heat-dissipating shields. Amplifier gain is stabilized by partial negative feedback. Non-lash, non-wearing, toothed belt drive gives long consistent performance.

Superior Operating Conveniences — Recorder function is easily changed by plug-in input units. Presently standard are 2.5, 5, or 10 millivolt d-c electrical spans . . . special applications and ranges are easily accommodated. "Micrometer" control for zero adjustment and main amplifier gain control are readily accessible as are all other adjustments, connections, and controls. The popular 10-speed chart gears and the high-capacity, easy-prime ink handling system proved on the "recti/riter"® recorder are standard equipment on the "servo/riter" recorder.

There are four "servo/riter" recorder models to choose from . . . *Single Channel, Narrow Grid; Single Channel, Wide Grid*; *Dual Channel, Narrow Grids; and Dual Channel (overlapping pens), Wide Grid*. Write for technical literature and TI engineering assistance in your specific end or OEM use.

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The new "servo/riter" recorder is a companion to the proved "recti/riter" recorder.

*"servo/riter" is a trademark of Texas Instruments

207

CIRCLE 155 ON READER SERVICE CARD

BULLETINS AND CATALOGS

(350) ENCLOSURE CATALOG. Automatic Electric Co. Catalog 4083-A, 32 pp. Uses 70 photographs and 150 line drawings to illustrate a complete line of hermetically sealed and protective enclosures for relays, switches, and control packages. Also refers to free booklet on relay terms and basic circuits and a frequency relay templet for circuit designers.

(351) LEAK DETECTORS. General Electric Co. Booklet GET-2935, 4 pp. Provides detailed information on how to use halogen-sensitive vacuum leak detectors in the laboratory and in production to locate leaks down to one millionth cc per sec.

(352) METERING PUMPS. Wallace & Tiernan Inc., Belleville, N. J. Catalog file 420.00, 12 pp. Covers the design, operation, construction, and dimensions of the company's Series 200 heavy duty metering pumps in simplex, duplex, and triplex arrangements. Full page table provides capacity pressure-selection data.

(353) RECORDING OSCILLOGRAPH. Consolidated Electrodynamics Corp. Bulletin 1536C, 16 pp. Deals with CEC's Type 5-119 recording oscillograph and various accessory equipment. Latter includes an electronic flash timing system, special types of record magazines, and a special mobile power supply.

(354) PHOTO TRANSISTORS. General Transistor Corp. Brochure G-190, 8 pp. Provides useful information on the operation and application of PNP germanium alloy junction photo transistors. Maximum ratings, cutoff characteristics, and typical small signal characteristics are tabulated for each of four types.

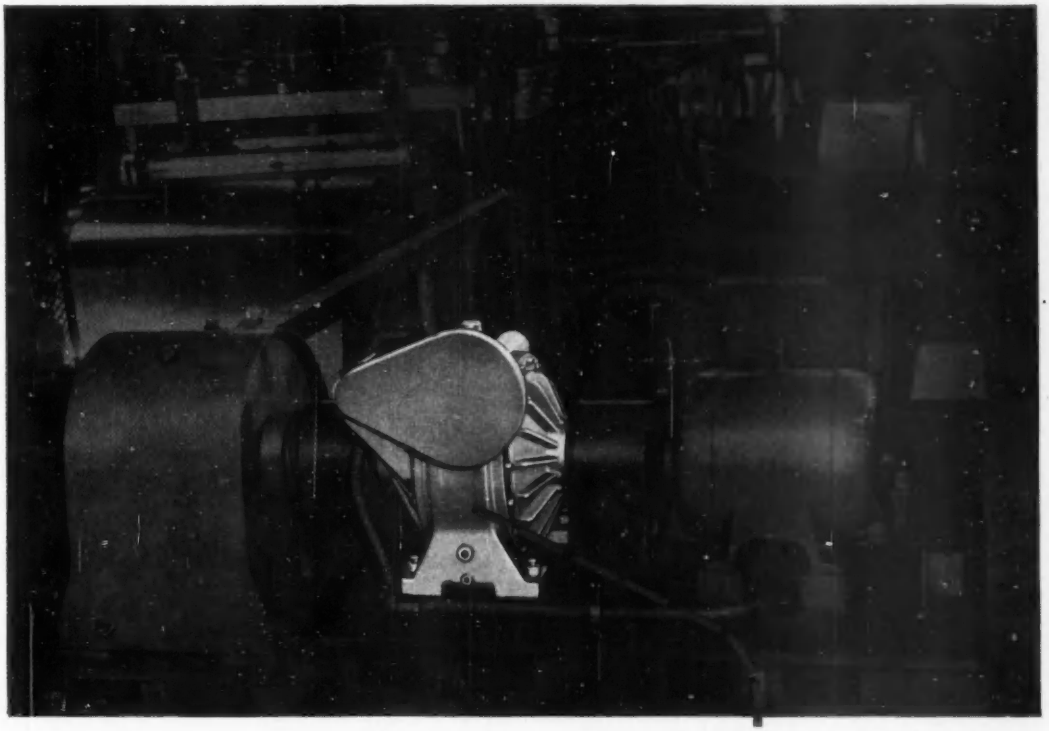
(355) SIZE 8 SERVOMOTORS. Helipot Div. of Beckman Instruments Inc. Catalog, 16 pp. Photographs, dimension and schematic drawings, and typical torque-speed curves amplify descriptive data on complete Size 8 servomotor line.

(356) LOGIC SWITCHES. Tally Register Corp. Catalog, 8 pp. Points out the advantages of Tally logic switches over standard relays in delayed logic circuitry. Applications cited include shift registers, translators, and verifiers.

(357) RECORDER/REPRODUCER. Ampex Corp. Bulletin, 20 pp. Contains an unusual amount of information on the new general purpose FR-100B magnetic tape recorder/reproducer. Performance figures for direct, FM, pulse duration modulation, and digital recording applications are included.

(358) WASTE TREATMENT. Minneapolis-Honeywell Regulator Co. Industry bulletin B97-2, 24 pp. Entitled "Instrumentation for Treatment of Industrial Wastes", bulletin contains 10 article reprints from Honeywell's *Instrumentation* magazine. Offers some interesting case history on how instruments are applied to industrial waste systems to prevent stream pollution.

(359) RATE TURNTABLES. Sterling Precision Corp. Catalog 152, 16 pp. Includes descriptions and specifications on



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This electrically remote-controlled unit is shown driving the line's conveyor pay-off reel station. All Clevelands feature simple, precise construction which makes for a compact, quiet-running, instantly-adjusted drive.

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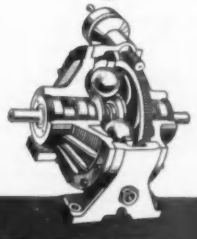

HOW IT WORKS

Power is transmitted from input shaft to output shaft through alloy steel driving balls which are in pressure contact with discs attached to the two shafts. Relative speeds of the shafts are adjusted by changing the positioning of the axles on which the balls rotate (see cutaway view, right).

CLEVELAND SPEED VARIATOR

rate turntables and other instruments for testing gyros, antennas, accelerometers, and guidance assemblies.

(360) PACKAGED SYSTEMS. Hagan Chemicals & Controls, Inc. Bulletin MSP-163, 6 pp. Offers complete details on the PowrMag solid-state analog computer control systems. Diagrams illustrate some of the many interchangeable computing circuits.

(361) SNAP-ACTING DISCS. Metals & Controls Div. of Texas Instruments, Inc. Booklet, 3rd edition, 29 pp. Entitled "The Story of the Spencer Disc", this booklet describes the origin and operation of the snap-acting disc-type thermal element. It explains how the disc actuates Klixon thermostats, circuit breakers, and inherent overheat motor protectors.

(362) PULSE TRANSFORMERS. Pulse Engineering, Inc. Catalog, 24 pp. Serves as both catalog and application manual. Sections cover definitions, pulse transformer theory, application aids, tolerances, and pulse transformer types.

(363) METERING PUMP. Associated Control Equipment, Inc. Bulletin No. P-21, 4 pp. Describes the operating principles of the Servo-Gauge metering pump and illustrates five typical applications. Design data include maximum capacity, operating characteristics, stroking rate, and power requirements.

(364) POT TEST DATA. Helipot Div. of Beckman Instruments, Inc. Report, 16 pp. Certified test report leaves no statistic unturned in describing the Series 50 Helitrim trimming potentiometer and should be of particular interest to engineers with potentiometer stability problems.

(365) NOISE PROBE. Erwood, Inc. Bulletin, 4 pp. Covers performance characteristics and typical applications of the Model 101B Electro Probe, an instrument designed to detect and measure noise and vibration in machines and mechanical systems.

(366) MOTOR CONTROLS. General Electric Co. Catalog GEC-1260D, 72 pp. This general purpose control catalog provides complete product descriptions of motor starters both—manual and magnetic, contactors, relays, solenoids, limit switches, pushbuttons, static controls, and pilot devices. Also includes wiring diagrams, dimensions, application data, and prices.

(367) INDUSTRIAL THERMOMETERS. Precision Thermometer & Instrument Co. Bulletin F2, 4 pp. Describes and illustrates a line of industrial thermometers in air duct, moisture-proof, and special MultiForm models. Lists temperature ranges and types of construction available.

(368) CIRCUIT BREAKERS I-T-E Circuit Breaker Co. Bulletin No. 5001-1A, 40 pp. Gives ratings, specifications, and operating characteristics on a complete and diversified line of molded case circuit breakers. Serves as an application guide for designers, contractors, and consulting engineers.

(369) TEST EQUIPMENT. Digital Equipment Corp. Bulletin, 4 pp. Describes DEC's 3000 Series digital test

TRY THIS TEST

Stare at the TMI core in the center of the red area for 30 seconds. Then look at a blank wall. Your eyes will reproduce the TMI core on a blue background (if it's any other color, write Telemeter Magnetics)

Our thinly disguised reason for presenting this optical phenomenon is to call your attention to the science of ferrite core manufacture as practiced at TMI. You can look to Telemeter Magnetics for top quality magnetic cores for any data storage application; for switching and other logic functions; and for special designs and characteristics to your specifications.

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pioneers in development and manufacture of core memory products

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Bulletins & Catalogs

equipment, a line of low speed, low cost building blocks suitable for educational and control applications.

(370) VERTICAL INDICATOR. Lear, Inc. Bulletin, 4 pp. Covers chief advantages of a new miniature standby vertical gyro indicating system which boasts a 2-in. panel-mounted indicator. Dimension drawings and complete engineering data are included.

(371) PHASE SEQUENCE CONTROL. Master Specialties Co. Bulletin No. 2001, 4 pp. Tells how this company's Phase Sequence Relay provides automatic monitoring of three-phase power.

(372) VERSATILE PUMP. Vickers, Inc, Bulletin A 5232-A, 10 pp. Offers complete details on a new 5,000-psi axial piston, variable delivery hydraulic pump for use in test systems, missile launchers, engine starting systems, etc. Illustrations include a photo and schematic of the pump, a typical application circuit, and a series of performance curves.

(373) 8 VALVE DESIGNS. Continental Equipment Co., Div. of Fisher Governor Co. Bulletin 50-1, 4 pp. Tabulates information on the size, applications, and performance of eight different types of butterfly valves, designed for use with either manual or power actuators.

(374) DATA LOGGERS. Hansen-Gorrill-Brian, Inc. Bulletin, 12 pp. Describes the Data-Master line of automatic data loggers: where they are used and how they operate. Covers four basic types, pointing out the standard and optional features of each.

(375) TAPE HANDLER. Ampex Corp. Brochure, 8 pp. Covers design details of the FR-400 digital magnetic tape handler and emphasizes mechanical highlights of its takeup and tensioning system. Also includes a full page of specifications.

(376) SUBMINIATURE SERVO KIT. Servo Development Corp. Brochure, 16 pp. Contains complete details on a new breadboarding kit for subminiature servos. Illustrates one typical assembly and gives prices and dimensions of individual parts.

(377) INDICATOR LIGHTS. Master Specialties Co. Catalog 159 C, 12 pp. Describes the Roto-Tellite line of rotating word lights for panel indicators. Diagrams cover a wide variety of standard ac and dc circuits as well as outline and mounting dimensions.

(378) HYDRAULICS LINE. The Oilgear Co. Bulletin 10051-H, 16 pp. Reviews a complete line of fluid power equipment including pumps, motors, transmissions, servo components, cylinders, and valves. Photos and specification tables accompany the descriptions.

(379) TEMPERATURE REGULATORS. Warren Engineering Co. Bulletin 502, 16 pp. Discusses the design, operation, and typical applications of several types of self-contained temperature regulators. Capacities of various valve sizes are tabulated in terms of gallons of water heated and pounds of steam consummed at different steam pressures.

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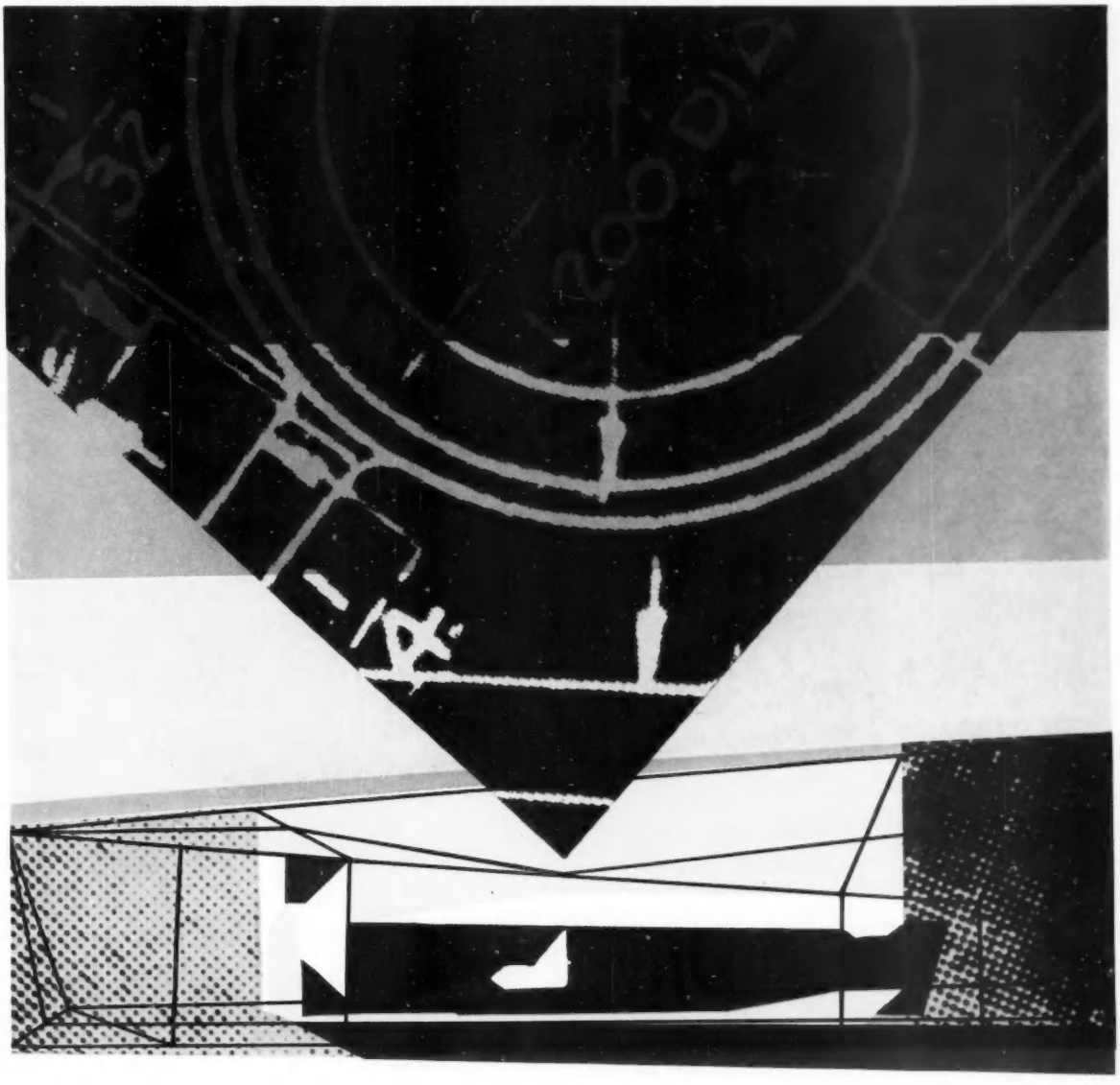

AC Seeks and Solves the Significant—Since GM has pledged its resources to this nation's defense, AC plans to forge to the forefront in the international race for technological superiority. The resolution of scientific problems even more complex than AChiever inertial guidance—that's what AC now has on its agenda / This is AC QUESTMANSHIP. It's an exciting creative quest for new ideas, methods, components and systems . . . to promote AC's many projects in guidance, navigation, control and detection / Questmanship is readily apparent in AC Manufacturing, headed by Mr. Roy McCullough, AC Works Manager. His group "offers an outstanding challenge to engineers capable of understanding the most advanced scientific concepts . . . and developing the techniques and tools to implement those concepts on a production basis" / There may be a position for you on our specially selected staff . . . if you have a B.S., M.S. or Ph.D. in the electronics, scientific, electrical or mechanical fields, plus related experience. If you are a "seeker and solver," you should write AC's Director of Scientific and Professional Employment, Mr. Robert Allen, Oak Creek Plant, Box 746, South Milwaukee, Wisconsin.

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Electronic Engineering With a Dimension for the Future

(Continued from page 47)

IMPORTANT MOVES BY KEY PEOPLE

New Exec at Monroe From Smith-Corona Marchant

Drummond Gaines is the new executive vice-president of Monroe Calculating Machine Co. Div. of Litton Industries, coming from Smith-Corona Marchant, where he was vice-president. He was with National Cash Register Co. for 8 years.

Gaines will head a group which is directing Monroe's expansion into new areas of the office machine field. He'll also take part in work with Monroe's recently acquired (CtE, Jan. '60, p. 58) Sweda Cash Register organization.

Rathje Heads Development At Teleregister

The Teleregister Corp., maker of automatic data processing systems in Stamford, Conn., has appointed Edward Rathje, Jr., as manager of its development section. Rathje has spent the past 5 years with Sanders Associates, Inc. in several positions including administrative assistant to the vice-president. He was previously with Daystrom Instrument Co. and Stavid Engineering, Inc.

Stromberg-Carlson Raises Two to V-P, Assistant

Kenneth M. Lord has been promoted to the position of vice-president and general manager of the Electronics Div. of Stromberg-Carlson, a division of General Dynamics Corp. The Rochester, N. Y., firm also named Dr. Nisson A. Finkelstein assistant vice-president and director of research.

Lord has been director of engineering in the Electronics Div.; he joined S-C in 1958 from the General Electric Co. Dr. Finkelstein has joined the company from a position as assistant director of the Scientific Bureau of the Bausch & Lomb Optical Co.

Rieder in New Post At Norden's Data Systems

The position of operations manager for the Data Systems Dept. of Norden Div., United Aircraft Corp. will be filled by Rudolph A. Rieder.

The job includes responsibility for manufacturing, material control, facility maintenance, and industrial engineering. Among the devices manu-

WHAT'S NEW

factured by the Gardena, Calif., department is the new electronic vote tallying system for Los Angeles County (see p. 65). Prior to joining Norden, Rieder served 6 years with Librascope, Inc.

Dr. Leone Becomes Manager of Rheem Califone

Vice-president and general manager of Rheem Califone Corp., a subsidiary of Rheem Manufacturing Co., is Dr. William C. Leone. Rheem recently acquired the 12-year old firm, a manufacturer of language labs, sound systems for schools, and teaching machines. Expansion is planned around Rheem's recently announced line of teaching machines, (see CtE, Nov. '59, p. 202). Dr. Leone joins the Los Angeles firm from Hughes Aircraft where he was manager of an industrial systems group.

Wells Runs Engineering For Aircraft Armaments

Aircraft Armaments, Inc., Cockeysville, Md., has raised its chief electronics engineer, Raymond W. Wells, to the post of director of engineering. He will manage the company's six engineering departments: Electronics, Electro-Mechanical, Structures, Ordnance, Aerodynamics & Nuclear Physics, and Engineering Services.

Wells has been with AA, Inc. since 1953. He joined the company after 6 years with the Glen L. Martin Co., from which AA, Inc. drew much of its early talent.

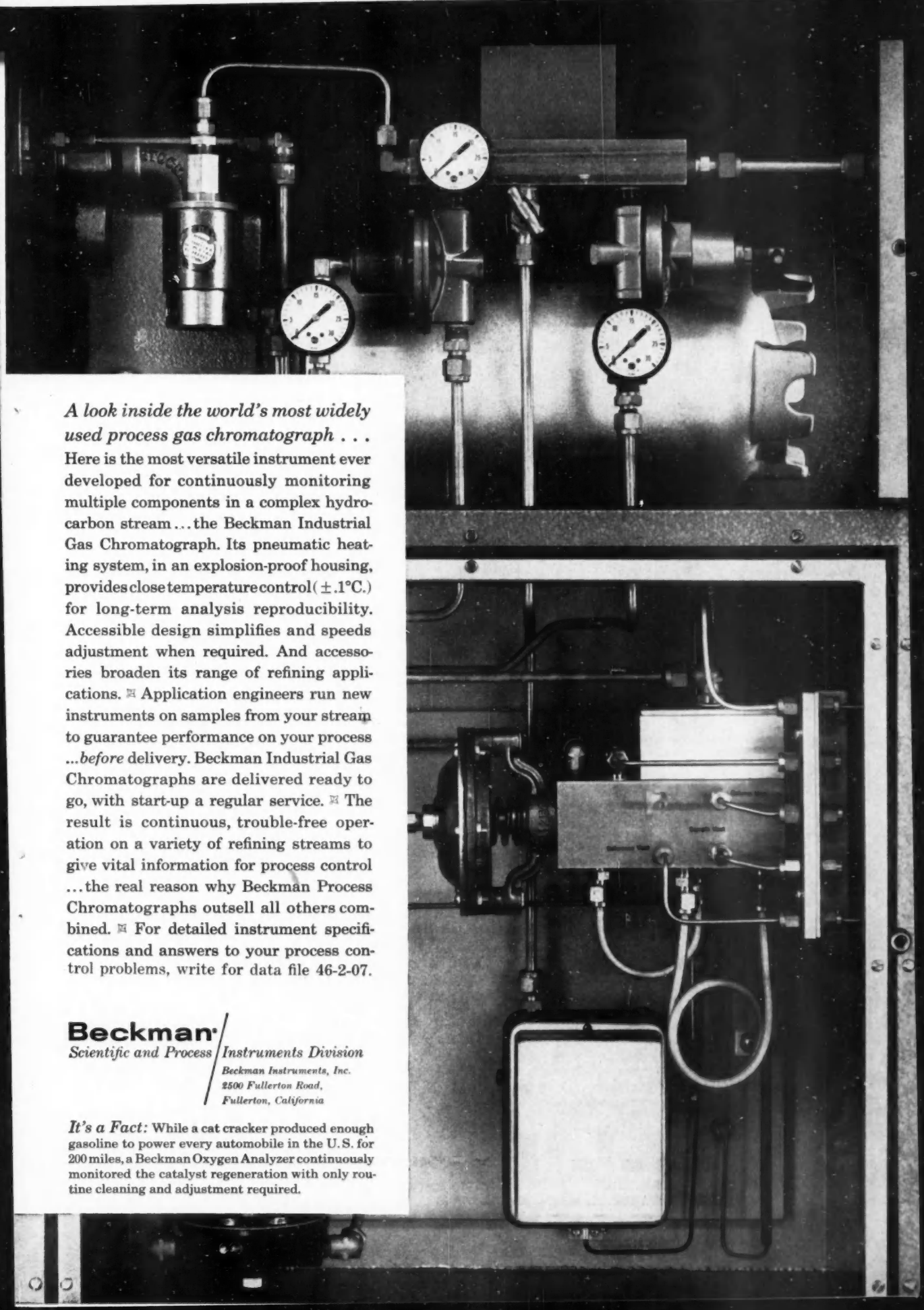
Kellogg Adds Griebel As Vice-President

Richard H. Griebel has accepted a position as vice-president and general manager of Kellogg Switchboard and Supply Co., the communications division of International Telephone and Telegraph Corp.

Griebel has been manager of manufacturing since 1957 at Raytheon Co. and had a similar post with Farnsworth Electronics Co. for 5 years. The post he fills at the Chicago company was vacant for 3 months.

RCA's Industrial Products Elevates Kunsman, Jones

Donald F. Kunsman will be the new general manager of the Electronic Data Processing Div., Industrial Electronic Products of Radio Corp. of



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It's a Fact: While a cat cracker produced enough gasoline to power every automobile in the U.S. for 200 miles, a Beckman Oxygen Analyzer continuously monitored the catalyst regeneration with only routine cleaning and adjustment required.

WHAT'S NEW

America, and Loren F. Jones will be manager of product planning of IEP as the result of promotions announced by the Camden, N. J. firm.

Kunsman has been president of RCA Service Co. since Sept. 1958, having joined the company in 1949. Jones has been with RCA since 1930 with experience in fields ranging from broadcasting to computers.

Other Important Moves

Dr. Lloyd T. DeVore is now director of engineering for the Laboratories Div. of Hoffman Electronics Corp., Los Angeles. The move is aimed at more effectively coordinating the division's research and engineering activity with the advanced research at Hoffman's Science Center in Santa Barbara, which Dr. DeVore also heads.

John A. Beckman, formerly of Hughes Aircraft Co., has become manager of communications and space projects for Houston Fearless Corp., Los Angeles. He'll be part of a program emphasizing advanced data transmission equipment, particularly for space communications.

John R. Curran is the new divisional vice-president and general manager of the Hammel-Dahl/Foster Engineering Div. of General Controls Co. Curran will be in charge of all engineering, production, and sales of the firm's line of control valves, regulators, safety and reducing valves, and flow tubes from a new plant in Warwick, R.I.

Alfred H. Faulker is newly appointed technical director of Datran, a division of Automation Industries, Inc. of Manhattan Beach, Calif. He was a senior staff engineer for Telemeter Magnetics, Inc. before joining the Datran organization.

H. D. Farnsworth has been named manager of product planning at Sierra Electronic Corp., a division of Philco Corp. Prior to joining the Menlo Park, Calif., company Farnsworth was with Stromberg-Carlson. He was employed by Philco for 10 years previous to his S-C association.

Helmut Walther is now chief engineer for the Electro-Mech Corp., custom control system builder of Norwood, N.J. Walther was formerly with Siemens & Halshe AG of Baden, Germany.

ASCOP

NEW

13 BIT ALL-MAGNETIC Shaft-Position Digital ENCODER

In any environment, in all applications, ASCOP magnetic encoders have proved to be rugged and tough. Our customers say that nothing compares to them for endurance and perfect performance under the worst conditions.

Now ASCOP has taken the same unique magnetic readout principle and incorporated it into a neatly miniature, ruggedly simple design to read out shaft positions to one part in 2^{13}. Parallel output is in binary code and total count is reached after 64 turns of the precision shaft and gearing. Lead-lag head arrangements assure that external decision making circuitry is minimized. The new ASCOP encoder operates in either direction and can be read out at rest or on-the-fly at speeds up to 10,000 rpm with equal facility. Since the only contacting parts are shaft and gearing, these are the only factors affecting life.

Condensed Specifications

Total Count: 2^{13} achieved in 64 turns of input shaft
Size: ..... 2¼" dia. x 3⅛"
Code: ..... Binary with lead-lag heads
Output: ..... Parallel
Weight: ..... 16 ozs.
Inertia: ..... 70 gm-cm²
Breakaway Torque: ..... 0.05 in. oz.
Max. RPM: ..... 10,000 rpm
Expected Life: 20,000 hrs. at 4000 rpm (expected bearing and gear life)

Brochure, price and applications notes on request

ASCOP a division of **ELECTRO-MECHANICAL RESEARCH, INC.**
P.O. BOX 44 • PRINCETON, NEW JERSEY

CIRCLE 169 ON READER SERVICE CARD 169

ABSTRACTS

Attractive projects

From "The Selection of Projects for Industrial Research" by C. M. Mottley and R. D. Newton. Operations Research, pp. 740-751, November-December 1959.

"Research organizations have a tendency to propose problems for investigation at a faster rate than resources can be supplied to support the work. This poses a fundamental issue for the managers of industrial research because there are always more ideas and problems to be investigated than the available resources will permit. Research management, therefore, is faced with the problem of selecting the set of projects that it expects will achieve maximum effectiveness for the company." Following this introductory statement, the authors proceed to lay down a method for selecting projects in applied research that are directed toward the creation of new products, processes, and uses for the economic survival of the sponsoring company.

The interesting aspect of this article is that, like so many others, the ideas it conveys can be applied to broader areas of interest. While the authors express their subject in terms of applied research, there is no reason, in the abstractor's opinion, why these same ideas cannot also be used with equal value in selecting worthwhile engineering projects.

The selection of projects can be reduced to five basic criteria, each of which has an indirect relation to future profits:

What is the best estimate of the promise of technical success consistent with known economics and the state of the art?

How long will it take to complete the research effort from this time forward?

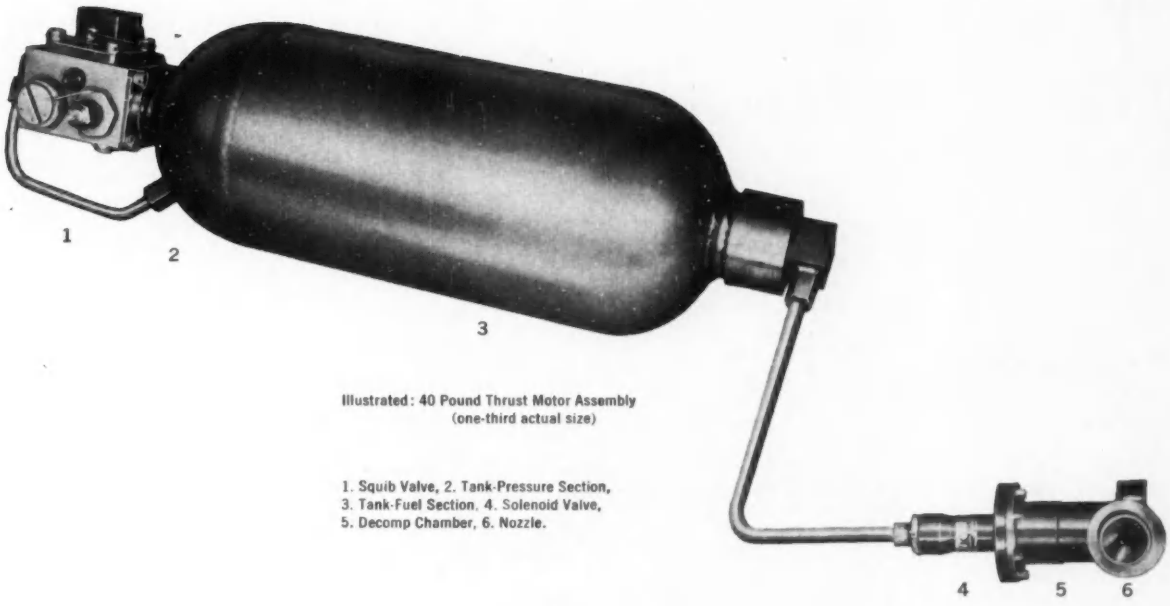
How much will it cost to complete the research effort from this time forward?

To what extent is successful research needed from a market standpoint?

What is the net market gain potential for the company after taking into account losses through product replacement?

The questions are referred to appropriate experts who, because exact answers are impractical at the outset of investigation, simply rank the answers from one to three. For instance, the range of answers for the question on market gain can be:

Less than $1 million/yr 1



Illustrated: 40 Pound Thrust Motor Assembly
(one-third actual size)

1. Squib Valve, 2. Tank-Pressure Section,
3. Tank-Fuel Section, 4. Solenoid Valve,
5. Decomp Chamber, 6. Nozzle.

REACTION CONTROL SYSTEMS BY KIDDE are highly reliable, now in production. Today being used on the NASA Scout, Air Force Thor, and the Air Force HETS, they are low in cost, light in weight, highest in performance. Kidde systems use mono-propellant, bi-propellant, cold gas, or solid fuels. Thrust motors from 2 to 600 pounds. For repeatability, response, and reliability in reaction control equipment, Kidde can serve you best! Write to Kidde today outlining your reaction control requirements.

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CIRCLE 171 ON READER SERVICE CARD 171

ABSTRACTS

$1 million to 10 million/yr 2
Greater than 10 million/yr 3

A single numerical score for a project is developed by multiplying the scores of the individual criteria, multiplication being chosen merely because it spreads out the sale of possible scores from a best rating of 243 to a minimum of one.

Once all proposed projects have been scored, the score vs the proposed budget expenditure for the ensuing year is plotted, and by accumulating these expenditures beginning with the highest scoring project, insight may be gained as to project-mix or program that appears to have the highest promise for the company for any limited budget figure. Such a plot exposes the merits and deficiencies of those factors causing a high or low score. An example based on 30 projects is worked out in the article.

Further insight can be gained by presenting the relations between the technical and commercial features of proposed projects. By interrelating the five criteria two at a time, 10 different pairs are possible, but of these, two are usually of the greatest interest to managements:

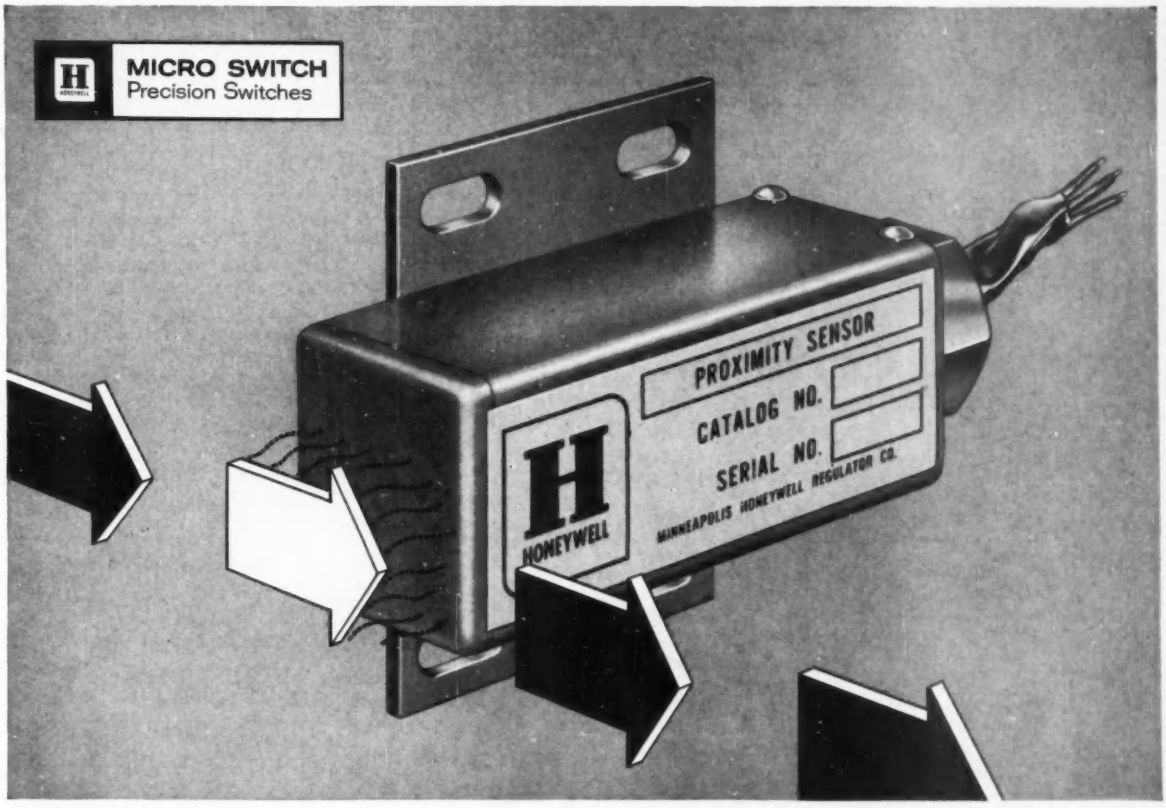
Market-gain vs promise of success
Market-gain vs time to completion

Data is entered in nine cells representing the different combinations of ratings for the two criteria, with rating 1-1 at the lower left and 3-3 at the upper right. In each cell are placed the number of projects for its rating combination and its percentage and the budget expenditure and its percentage. Additional cells along the top and right accumulate the totals of each rating for the two criteria. In this case also, illustrative examples are shown in the article.

New tape technique

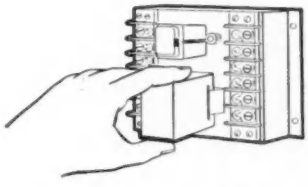
From "Thermoplastic Recording" by W. E. Glenn, General Electric Research Laboratory. Journal of Applied Physics, pp. 1870-1873, Vol. 30, No. 12 December 1959.

A new method for recording high density electrical information signals on tape is described. The tape consists of a high-melting base film coated with a transparent conducting coating having a thin film of a low-melting thermoplastic on its surface. An electron beam lays down a charge pattern on the surface of the thermoplastic according to the information to be stored. Heating the film to the melt-

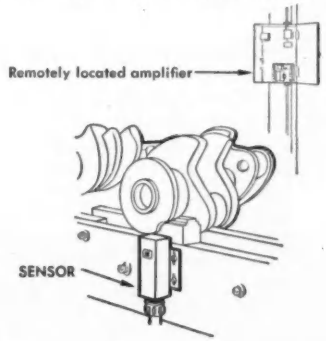


Actual size: 1.63 x 1.63 x 3.75

BUSY SWITCH
without a moving part!



Plug-in relay in amplifier cuts downtime.



Amplifier is separate, may be remotely located.

Honeywell Proximity Switch opens new ideas for up-dating machines and methods

This amazing new switch solves many automation problems that previously could not be tackled. It detects metal parts that pass within ½" of the sensor—over 600 operations a minute—without ever touching them. Perfect answer where rough parts or corrosive atmosphere may damage a mechanical switch or where the delicate finish of a product might be marred by physical contact.

The Honeywell sensor has no moving parts to wear out, need never be replaced! It has a rugged stainless steel face. The sensing unit is sealed against cutting oils, filings, humidity, sand and dust, can operate submerged if necessary.

A Proximity Switch can be your answer to difficult switch problems, but be sure it is a product of Honeywell research. Contact the nearby MICRO SWITCH branch office and ask for Data Sheet No. 163.

MICRO SWITCH, FREEPORT, ILLINOIS
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In Canada: Honeywell Controls Limited, Toronto 17, Ontario

Honeywell
MICRO SWITCH Precision Switches

CIRCLE 173 ON READER SERVICE CARD 173

ing point of the thermoplastic causes electrostatic forces to depress the surface where charges occur, until these forces are in equilibrium with surface tension restoring forces. Cooling the film freezes the deformations into the surface. For erasing the stored data, the thermoplastic film is heated well above its melting point so that surface tension smooths out the deformations.

For color imaging, the deformations are impressed on the thermoplastic surface in the form of diffraction gratings, with an optical system projecting the color image from the pattern of gratings. For black and white images the entire light spectrum is passed by the optical system.

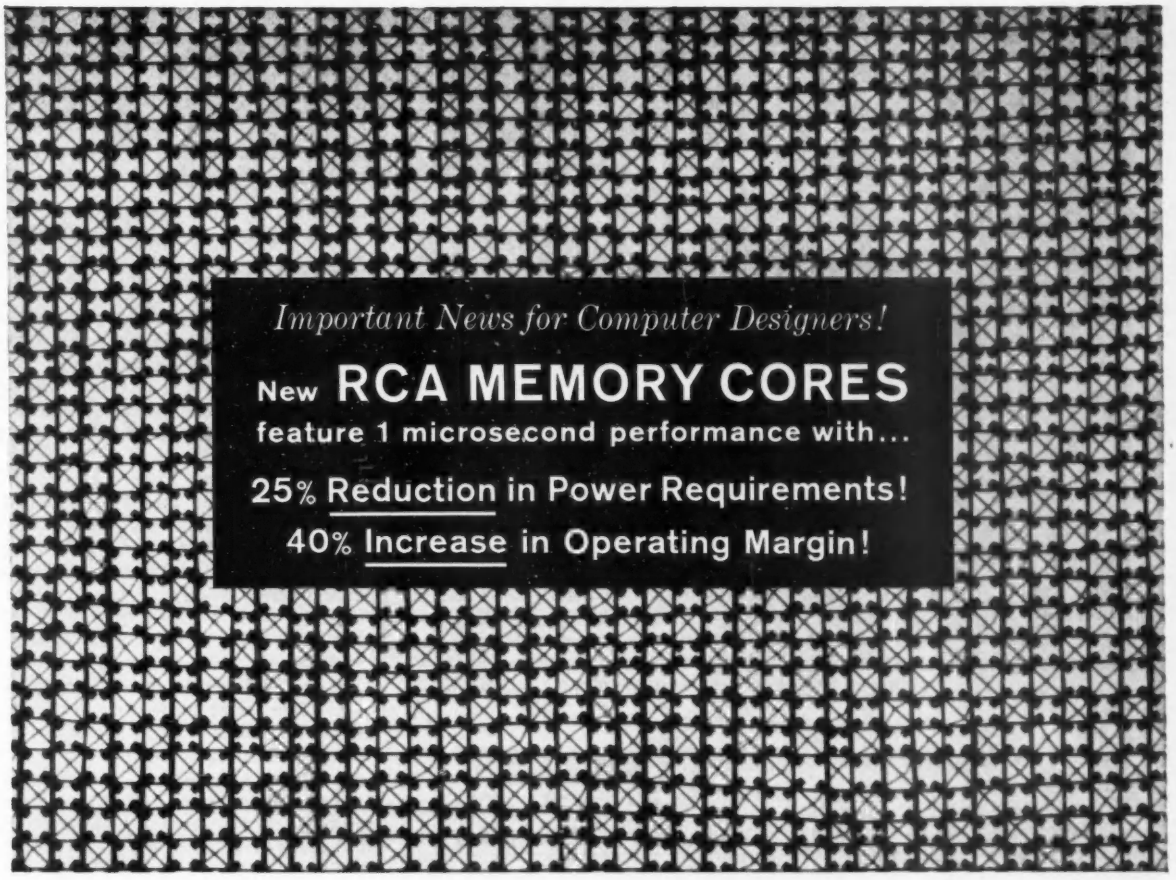
To produce an electrical output, a flying spot scanner or camera tube is used with the optical system. To record electrical signals in analog form, the electron beam is modulated by the signal. For binary digital data a single split beam may be used. In this case it is desirable to use only two colors, one for 0's and another for 1's so that all data bits appear as the presence of a single color.

Briefly noted

From "Flight Testing of Automatic Stabilization and Control Systems in Manned Aircraft", by H. W. Turner, 1958, 23 pp. AGARD Report 192, North Atlantic Treaty Organization, Advisory Group for Aeronautical Research and Development.

The increasing use of automatic flight stabilization and control systems has opened a fresh field of flight evaluation work. Test procedures in this field are less well established than those for, say, basic aircraft stability measurements, and the purpose of this note is to summarize the procedures which have been evolved at the Aeroplane and Armament Experimental Establishment, Boscombe Down, England.

Two types of automatic control systems are discussed: auto-stabilization systems with limited control authority, and autopilot systems (or automatic pilots) which may have considerable control authority. Test instrumentation for these two types is also discussed, and the procedures and techniques used to evaluate the aircraft-automatic control system combination for a particular mission are described.



Dramatic improvement over present standard cores offers greater design flexibility, top performance in high-speed coincident current memory applications

New 1-μ sec memory cores 226M1 (XF-4028) and 228M1 (XF-4257) developed at RCA's Materials Lab in Needham Heights, Mass., represent an important step forward in ferrite core design for military and commercial computers. See chart for the significant improvements in power requirements and operating margin now possible in 1-μ sec operation.

Call your local RCA Field Representative and learn how the new 226M1 and 228M1 can fit into your new computer designs. He can also give you information on the entire line of RCA Ferrite Memory Cores, Planes and Stacks available to meet your specific design requirements. For technical data, write RCA Commercial Engineering, Section B-56-NN, Somerville, N. J.

NOMINAL OPERATING CHARACTERISTICS AT 25°C							
Type	Size	Full Driving Current (Im) (ma)	Partial-Write Current (Ipw) (ma)	Pulse Rise Time (T_r) (μsec)	Switching Time (T_s) (μsec)	Response	
						"Undisturbed 1" (μV_1) (mv)	"Disturbed 0" (dV_0) (mv)
228M1 (XF-4257)	.080" x .050" x .025"	620	310	0.2	1	160	18
226M1 (XF-4028)	.050" x .030" x .015"	380	190	0.2	1	75	10

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NEW BOOKS

Analog Primer

PRINCIPLES OF ANALOG COMPUTATION. *George W. Smith and Roger C. Wood. 245 pp. Published by McGraw-Hill Co., Inc., New York. $7.50*

This text has been used as the basis of a course in analog computation presented to seniors and first year graduate students in the physical sciences. Its emphasis is on the techniques of analog computation and not on computer design. In Chapter 1 the authors describe the major components comprising a modern analog computer installation. In the process of deriving the general equation for an operational amplifier, they discuss setup procedures for both the committed (REAC, PACE, EASE) and the uncommitted (GEDA, Donner) types. In their discussion of potentiometers, they present some useful equations and curves which enable the computer operator to compensate for potentiometer loading effects. This chapter also contains a treatment of various types of analog multipliers, servo resolvers, output devices, and problem boards.

Chapter 2 on problem planning and programming starts with a good discussion of problem scaling, with both amplitude and time transformations treated in detail. Transfer function simulation and generalized integration are also thoroughly explained. The last part of the chapter contains several excellent examples worked out in considerable detail. In Chapter 3 the authors present the two basic methods for simulating linear systems: solution of the system differential equations and the use of special impedance functions. Both methods are described in detail with examples illustrating practical programming techniques. The authors then analyze a so-called "five-impedance network" as a means of simulating a second order system with only one amplifier. They include some nomographs that permit the computer operator to select circuit component values with a minimum of computation. The chapter's closing section contains an interesting discussion of techniques for simulating dead time. Instead of using the conventional Pade approximations for e^{-T_s}, the authors prefer to apply straightforward curve-fitting techniques to the phase characteristic and use the resulting equations for simulation. They show that it is possible to simulate dead time using polynomials obtained by curve-

fitting and achieve about 30 percent more bandwidth than with Pade approximants.

Chapters 4 and 5 deal with the use of diodes and relays in analog computations. Various nonlinear circuits, such as limiting, backlash, absolute value, comparator, etc., are constructed and analyzed in detail. Diode and relay switching techniques are compared in the concluding sections of Chapter 5, with the relative advantages and disadvantages of each presented. Chapter 6 is an extremely valuable treatment of implicit-function techniques, that is, using a high gain operational amplifier and closing its feedback loop through an appropriate computing element. Division, square root, inverse sine generation, and inverse tangent generation are discussed at great length; stability difficulties and indeterminate cases are briefly but adequately treated.

Chapter 7 covers arbitrary function generators, while Chapter 8 discusses the general theory of computer components and computer control circuits. Especially interesting is the description of a method for generating functions of two variables with conventional diode function generators.

In general, the authors have competently presented useful circuits and techniques for analog computer operators. This reviewer was somewhat disappointed to find no mention made of McDonnell Aircraft Corporation's report MAC 4966, "Techniques and Developments in the Analog Computer Field," since this report is (in the reviewer's opinion) the most comprehensive encyclopedia of analog computer circuits ever published. But the overall treatment is quite good; the book should prove useful both to engineering students taking a first course in analog computing and to practicing engineers who wish to learn the fundamentals on their own.

L. R. Axelrod
The Powers Regulator Co.

Theory Applied

FREQUENCY RESPONSE FOR PROCESS CONTROL. *William I. Caldwell, Geraldine A. Coon, and Leslie M. Zoss.* 395 pp. *Published by McGraw-Hill Book Co., Inc., New York.* $11.50.

Aided by six competent application and research engineers who were responsible for one chapter apiece, the three major authors, connected at one time or another with the Taylor Instrument Companies, have given us the eleventh book in the publisher's series in control systems engineering. Growing out of a constantly revised

NEW BOOKS

course that applied frequency response techniques to process control, the volume represents a happy combination of underlying theory and sound practical applications.

Among the topics of Part I (Basic Theory) are stability considerations, the properties and frequency response of linear lag, experimental procedures, feedback systems, the effect of process characteristics on proportional control, proportional-plus-reset control, three-term controls, closed-loop response, and location of disturbances in the control loop. Part II (Applications) deals in a clear manner with computation of process characteristics, dynamic testing of instruments, effect of temperature on automatic control, pneumatic transmission lines, pH control systems, and cascade systems.

Organization of material throughout is exceptionally good: the reader is led gradually from simple initial considerations to the intricacies of quite involved systems, the longer chapters end with terse but adequate summaries, and one appendix is devoted to the construction of time-saving templets. The theoretical portion of the book contains 130 problems, usually with answers. In all, 257 excellent line cuts fortify the text along with ample references to recent literature and a brief subject index.

Carefully edited, this volume constitutes an outstanding example of good technical exposition, highly but never unnecessarily mathematical. Attractive in format and well-adapted to classroom use, the book should also meet the requirements of the practicing engineer who must study alone.

D. S. Davis
University of Alabama

Polished Work

CHEMICAL ENGINEERING PLANT DESIGN (FOURTH EDITION). *F. C. Vilbrandt and C. E. Dryden. 534 pp. Published by McGraw-Hill Book Co., Inc. New York. $12.*

As one would expect in the fourth edition of a well known textbook, this is a polished piece of work. Indexing, references, and symbol tabulation are excellent, and the whole layout of the text is well planned. Chapters are offered on the development of the project before starting detail work followed by the process design, equipment selection, and layout stages. Economic evaluation and geographical location are followed by site preparation and structure considerations. Each chapter is well organized, with

many examples, and each follows naturally from the preceding one. The next to last chapter is on auxiliary equipment, with 62 pages of details on piping, 8 pages on power, and 15 on instrumentation. The control engineer may be disappointed in the latter coverage, but what is presented is excellent, with adequate references. A table of typical price ranges for instruments is complete and useful.

A timely feature of this book is Chapter 10, Nuclear Chemical Plant Design. To the best of the reviewer's knowledge, this is the first attempt to place directly in the chemical engineer's hands a text on this subject. Coverage is thorough enough (43 pages) to serve as an adequate introduction to the subject, and 91 references cover most of the standard sources. The health physics coverage is good, and many useful formulas and charts are presented. As must happen to every author in such a fast moving field, part of Table 10-2 became obsolete while in press; one must turn to government publications for the more up-to-date data.

Intermediate Text

CONTROL ENGINEERING. *Gordon J. Murphy, Northwestern University.* 385 *pp. Published by D. Van Nostrand Co., Inc., Princeton, N. J.* $7.50

Covering modern automatic control theory at an intermediate level, this book treats both elementary and advanced topics in some detail, filling the gap between general introductions and exhaustive treatments. The author draws problems and illustrations from many fields, including process control, fire control, inertial guidance, and nuclear reactor control. Following an introductory chapter is a discussion of time response, including a development of the Laplace transform that is applied extensively throughout the book. The characteristics of a number of control system components are then presented, and design in the complex domain (the s-plane) is covered. The use of frequency response techniques, a complete treatment of ac carrier systems, and the analysis of systems with time lag are also included. The author deals at length with sampled-data systems and the statistical analysis of linear control systems. The final two chapters are devoted to nonlinear control theory, including the use of describing functions and the phase plane.

WHAT'S AVAILABLE IN REPRINTS

The following reprints have been prepared to make important reference-type editorial material available to CONTROL ENGINEERING readers in convenient filable form. Some reprints are individual articles, while others are "packages"—several articles published over a period of time that logically supplement one another in the coverage of a specific phase of the control field. Any reprint can be obtained at the nominal cost listed below by filling in the order form and sending it, together with remittance, to Readers Service Dept. Quantity rates will be quoted on request.

How to Specify Instrument Accuracy, 8 pp. This basic reprint is aimed at helping the user and maker to develop clear and mutual agreement on allowable instrument errors. Discussions of uncertainties of zero, scale factor, and instantaneous slope aid in the intelligent specification of allowable errors and preferred test procedures. 40 cents.

Transparent Template for Designing Servo Compensators, November 1959, 3 pp. plus template. Includes transparent decibel vs phase angle template on clear acetate in addition to three-page Data File outlining development of template and showing its use through sample problem. 75 cents.

How to Use the Root Locus in Control System Design, 12 pp. Another reprint that translates theory into practice. Eight simple rules make locus construction easy, even including the effects of distance-velocity lags. Articles show how to interpret the locus diagram, how to

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Specifying Instrument Accuracy	$0.40		
Servo Compensator Template	$0.75		
How to Use the Root Locus	$0.45		
Complete Analysis Instrumentation	$1.75		
Analysis Instrumentation—III	$0.90		
Analysis Instrumentation—II	$0.60		
Analysis Instrumentation—I	$0.60		
Fundamentals of Multivibrators	$0.50		
Control System Test Equipment	$0.60		
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Report on Russian Control	$0.40		
Calculating a Control Index	$0.30		
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Applying Control Timers	$0.50		
Control System Reliability	$0.20		
Point-to-Point Positioning Systems—I, II & III	$1.50		
Ready Reference Data File—I	$0.50		
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Basic Data on Process Control	$0.50		
How to Simulate Dead Time	$0.15		
Power Amplifiers	$0.50		
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REPRINTS cont'd

determine transient response, and how to use locus techniques with multiloop systems. 45 cents.

Complete Analysis Instrumentation Series, 112 pp. Special rate for those who order all three parts (I, II, and III) of Analysis Instrumentation Series; 17 percent discount on 112 pages of timely technical information for process control engineers. $1.75.

Analysis Instrumentation—III—Electrochemical Methods, Mass Spectrometry, Continuous Viscometers, X-Ray Techniques, K-Capture, Physical and Chemical Property Testers, Emission Spectroscopy, 48 pp. Reprint includes last nine articles of Analysis Instrumentation Series. $.90.

Analysis Instrumentation — II — Refractometers, Infrared Analyzers, Photometric Analyzers, Colorimetry, 32 pp. This includes the second group of four articles of the Analysis Series. 60 cents.

Analysis Instrumentation — I — Nuclear Magnetic Resonance, Chromatography, Radioactivity, 32 pp. Reprint consists of first 4 articles of Analysis Instrumentation Series: a general introduction and detailed discussions of the three analysis techniques. Emphasis is on basic principles, practical tips, and the use of these techniques in automatic process control. 60 cents.

Fundamentals of Multivibrators, 12 pp. Multivibrators are the electronic equivalent of the double-throw electromechanical relay and can perform substantially the same functions (memory, logic, gating, counting), but at enormously higher speeds. They can be built around vacuum tubes, transistors, square-loop magnetic materials, neon tubes, thyratrons, and cryotrons. This reprint covers a broad selection of multivibrator circuits that are especially applicable to control systems. 45 cents.

A Roundup of Control System Test Equipment, 24 pp. Specialized control system test equipment divides into three classes: 1) devices that only generate a test signal, 2) systems that both disturb the system and provide a means for evaluating response, and 3) devices that only evaluate control system response. A survey of equipment and tips on using it. 60 cents.

Survey of Ac Adjustable-Speed Drive Systems, June 1959, 16 pp. Largely regarded as constant-speed devices, multispeed ac actuators actually take many efficient forms. The recent resurgence of interest in these ac adjustable-speed systems prompted this comprehensive coverage of pole-changing techniques, armature resistance control of wound-rotor motors, frequency changing, slip-frequency injection, and the use of eddy-current couplings. 50 cents.

A New Way to Select the Best Control Valve, 16 pp. This three-article reprint takes a fresh look at the problem of specifying process flow control valves. The author gives rules for selecting the right valve characteristics based on static and dynamic considerations, takes into account the influence of piping on valve performance, and tackles the problem of sizing valves for maximum flow and for control rangeability. 50 cents.

Continued on page 182

REPRINTS cont'd

Ready Reference Data Files—II, 24 pp. Includes the second dozen data files published in Control Engineering. Add it to Ready Reference Data Files—I to keep your personal file up to date. Topics covered range from analyzing hydraulic servos graphically to using silicon diodes as protective devices. 50 cents.

Fundamentals of Tie-Motor Control, 12 pp. Although high-powered synchro-tie systems have been around for a long time, only recently has enough experience been logged to put their design on a scientific, rather than cut-and-try, basis. This reprint examines the types of motors that can be used in the light of the application characteristics, and considers the special circuit designs that are required. 30 cents.

Applying Phase-Plane Techniques to Nonlinear System Design, 16 pp. This series of three articles is designed to teach the use of phase-plane techniques to working system designers, on a practical rather than theoretical basis. It tells how to construct a phase-plane plot, how to interpret a plot in terms of system performance, and how to synthesize nonlinear systems using phase-plane techniques. 50 cents.

Economics in Control, December 1958, 24 pp. A special report covering the economic aspects of modernizing with control systems. It starts off with a guide to the financial factors of modernization, then tells the control engineer how to spot opportunities where the addition of instrumentation and control equipment will earn money, and concludes with nine case histories showing specific benefits of modernizing with control systems. 50 cents.

First-Hand Report on Control Inside Russia, November 1958, 16 pp. A team of 14 U. S. control engineers representing the American Automatic Control Council reports on the status of automatic control in Russia. Each expert gives impressions of progress in his field of interest based on visits to Russian user plants and research facilities. 40 cents.

How to Calculate a Control Earning Index, 12 pp. Shows a four-step method for predicting the increment of improved plant economy resulting from the addition of instruments and controls, and reports on experience in applying this method to three typical industrial processes. 30 cents.

Servo Design Techniques, 32 pp. A reprint of six related articles describing various electromechanical servo design techniques. Items include tachometer limiting, force-reflecting servos, calculating performance of drag-cup tachs, dual-mode servo compensation, applying packaged servo actuators, and cascading resolvers without amplifiers. 65 cents.

What's Available in Flowmeters, 24 pp. A comprehensive coverage of positive displacement, velocity, and mass flowmeters, including characteristics, applications, and typical manufacturers; plus details of a special drag disc meter. 50 cents.

Selecting and Applying Control Timers, 24 pp. A compilation of four articles including a tabular description of timer functional parts, criteria for selecting and applying control timers, a tabular listing of available timer types and their charac-

REPRINTS cont'd

teristics, and techniques for custom-designing controls for time-based routines. 50 cents.

What the Control Engineer Should Know About Reliability, April 1958, 8 pp. Not intended as a comprehensive treatise, but rather as a guide to aim the control engineer in the right direction, this staff-written article discusses the new concept of systems effectiveness, and briefly covers techniques for measuring reliability, predicting reliability, improving reliability, and costing reliability. Up to date reference sources increase the value. 20 cents.

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Seventh Annual Solid-State Circuits Conference, sponsored by IRE, AIEE, University of Pennsylvania, Philadelphia, Pa. Feb. 10-12

First National Symposium on Nondestructive Testing of Aircraft and Missile Components, Society for Nondestructive Testing, Hilton Hotel, San Antonio, Tex. Feb. 16-18

MARCH

American Society of Mechanical Engineers, Hydraulic Division Conference (held jointly with Gas Turbine Power Conference), Rice Hotel, Houston, Tex. March 6-9

Instrument Society of America, Temperature Measurement Symposium, Deshler Hilton Hotel, Columbus, Ohio March 9-11

Synchro Design and Testing Symposium, Department of Navy, Bureau of Naval Weapons, Department of Commerce Auditorium, Washington, D. C. March 17-18

Institute of Radio Engineers, National Convention, Coliseum and Waldorf-Astoria Hotel, New York City March 21-24

22nd Annual American Power Conference, sponsored by Illinois Institute of Technology, Hotel Sherman, Chicago, Ill. March 29-31

APRIL

Sixth Nuclear Congress, sponsored by ISA and Engineers Joint Council, New York City April 3-8

Instrument Society of America, Symposium on Computers in the Process Industry, sponsored by N. J. Section, Hotel Essex House, Newark, N. J. April 5

Third National Chemical and Petroleum Instrumentation Symposium, Rochester, N. Y. April 5-7

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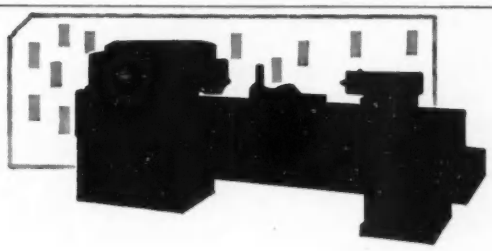

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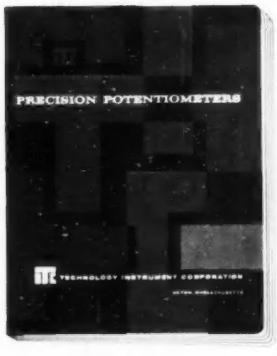

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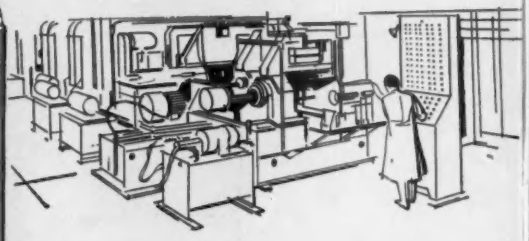

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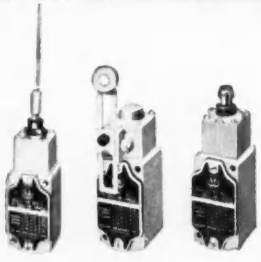

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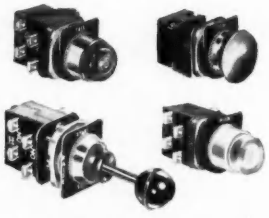

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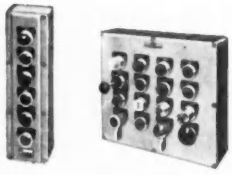

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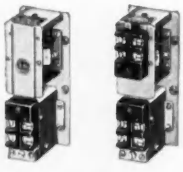

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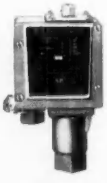

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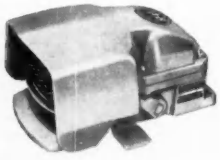

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